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ANALYSIS OF URINARY CALCULI BY ATTENUATED TOTAL REFLECTION WITH ATLAS

A Dissertation

Presented to

the Faculty of the Graduate School

University of Pacific

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Peter Tin-Kei Chan

July 1971

This thesis, written and submitted by

Peter Tin-Kai Chan,

is approved for recommendation to the Graduate Council, University of the Pacific.

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Emerson G Cobb

Dated Sept 9, 1971

ACKNOWLEDGMENT

The author gratefully acknowledges the guidance of Dr. H. Frye and the Department of Chemistry of the University of Pacific. Without whose help and valuable ideas this thesis would not have been written.

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CHAPTER I

INTRODUCTION

A urinary calculus is an abnormal concretion of the urinary tract usually composed of mineral salts. If it is found in the bladder it is referred to as a vesicle calculus, and if it is found in the pelvis of the kidney or ureter it is referred to as a renal calculus.

> The problem of urinary lithiasis remains unsolved despite a vast amount of clinical observation and experimental research. The factors of causation can only be stated in terms of broad and indefinite generalization and are believed to be linked with nutrition. Numerous specific exceptions to such factors are known to exist. Among a people with a notably high standard of nutrition, such as we have here in North America, the proposition becomes increasingly difficult. Prevention of calculus in the population at large may be dismissed without consideration in the light of our present knowledge. Prevention or recurrence in the susceptible individual, on the other hand, demands our best efforts--and we have not been too successful.(1)

Clinicians are becoming more and more concerned about the sharp increase of urinary calculi especially among the middle age group. They feel that there is a lack of the basic knowledge of the exact composition and the causes of urinary calculi. This is mainly due to the inadequate methods of analysis. Reliable analytical information is fundamental for a study of the etiology of their formation, and is essential for preventing their reoccurrence.

The purposes of this research are (1) to bridge this gap of deficiency by developing a simple, precise and reproducible routine analytical technic by using attenuated total reflectance, and (2) to serve as an atlas for identification of renal calculi.

CHAPTER II

THE FORMATION OF URINARY CALCULI

Knowing the formation and composition of the urinary calculus will help the clinician to determine its cause, and to prevent its reoccurrence.

Most urinary calculi start out with some kinds of lesion in the submucosa of the urinary tract. This could be caused by infection. Almost all urinary calculus patients have proteus, staphylococcus, streptococcus, or other bacterial infection. The calculi could be formed by (1) concretion and (2) sedimentation.

FORMATION BY CONCRETION

The lesion acts as a nucleus. When there is more irritation, the lesion could enlarge, and collect dead epithelial cells and other foreign bodies. If there is bleeding blood cells would deposit on the lesion. Thus the nucleus grows. When it is exposed to concentrated urine, urinary salts deposit on it. The deposition erodes away the submucosa, and after it has become a free calculus it can grow by having more urinary salt deposited on it. Occasionally it could be passed out with the urine. When the calculus has grown from the papilla of the submucosa there is an indentation. When the calculus is formed by concretion different layers from the center could be seen.(2)

FORMATION BY SEDIMENTATION

In a lesion there may be large deposit of foreign material. This results in different nuclei for the deposition of urinary salts. When this occurs the calculi have no fixed nucleus center, and there is no uniform layer deposited on it. When the overlying epithelium is worn out, the lesion will be exposed to the urine with heavily saturated salts which deposit upon it. As it grows the calculus tears itself away from the surface and becomes a free stone.

Keratinization due to deficiency of Vitamin A or small blood clot could form a nucleus upon which urinary salts could deposit. The dead epithelial cells could rapidly be calcified. Faulty calcium metabolism could cause stone formation.(3)

In calculus of pure triple phosphate the distinct nucleus cannot be identified. It forms a loose network of columns or pillars radiating from the center of the calculus. The uric acid calculus commonly has a nucleus composed of oriented uric acid crystals. The cystine calculus has the nucleus of oriented cystine crystals.

Hammarsten (4) has shown that in rats with high urinary calcium excretion and urinary low pH calcium oxalate calculi are formed readily. With an increase in pH calcium phosphate calculi are formed.

Table I

Types of Calculi formed and the pH of urine

pH	Types of Calculi Formed
5	uric acid
6	uric acid, calcium oxalate, calcium phosphate
7	Only calcium phosphate
8	Calcium carbonate Calcium phosphate, magnesium ammonium phosphate

(5)

The method to prevent calculus formation by a person with tendency to form uric calculi is to alkalinize the urine, and to acidify the urine of the patient with tendency to form phosphate calculi.(6)

CHAPTER III

THE COMPONENTS OF URINARY CALCULI

Prien, and Frondel (7) analyzed 1000 urinary calculi by mineralogic methods, and x-ray diffraction, and found the following to be the most common components. Their study is the most thorough single study of urinary calculi.

CALCIUM OXALATE, Ca_2O_4

The mineralogic name is Whewellite. It is usually found in acid and sterile urine. Based on external appearance Ord and Shattock described three types of calcium oxalate of the monohydrate and one type composed of dihydrate.(8)

The color of calcium monohydrate $CaC_2O_4.H_2O$ is light to reddish or black brown. It is very hard, porous, smooth and has a lustrous surface. Physical properties:

Hardness = 2-1/2 to 3. Specific gravity = 2.23.

Optical properties:(9)

X = 1.491 = b	Biaxial positive (+)
Y = 1.555	2V = 84°. Dispersion r<v, weak.
Z = 1.650	Extinction angle ZΛc = 31°

Calcium oxalate monohydrate is easily distinguished optically from calcium oxalate dihydrate, $CaC_2O_4.2H_2O$, by its high birefringence and high Z index of refraction.

The first type of the calcium oxalate monohydrate is the "hempseed" stone. It is smooth, oval in shape, and has concentric laminations. The second type is the "mulberry" stone which is shaped with irregular rounded mammillary processes, and has variable size. On cross section these rounded protuberances are seen to be composed of radially striated aggregates. The third type is the "jack stone" which has a central mass with radiating blunt spinous processes. It is rather uncommon, and is usually found in the bladder.(10)

CALCIUM OXALATE DIHYDRATE, $CaC_2O_4.2H_2O$

Calcium Oxalate dihydrate calculus is composed of either loose or compact interlocking aggregates of well formed octahedral crystals. Usually no nucleus is found in it. The color ranges from pale yellowish white to light honey brown. Pure calcium oxalate dihydrate is very rare. It is usually associated with calcium oxalate monohydrate, calcium hydrogen phosphate, cystine and uric acid. Physical properties:

Hardness = 4. Specific gravity = 1.99

Optical properties:(11)

O = 1.523 Uniaxial positive (+)

E = 1.444

APATITE

CARBONATE-APATITE	$Ca_{10}(PO_4,CO_3OH)_6(OH)_2$
HYDROXYL-APATITE	$Ca_{10}(PO_4)_6(OH)_2$

The term "apatite" refers to group of compounds which have an analogous chemical composition and identical crystal structure, such as carbonate-apatite and hydroxyl-apatite.

Carbonate-apatite, $Ca_{10}(PO_4,CO_3OH)_6(OH)_2$, may be described as a complex carbonated calcium phosphate; hydroxyl-apatite, $Ca_{10}(PO_4)_6(OH)_2$ is similar but contains no carbonate. Carbon-dioxide gas could be released from carbonate-apatite but not hydroxyl-apatite.

To test for CO_2 add a drop of dilute HCl to a few course grains of apatite on a glass slide under a cover glass. If CO_2 is present a brisk effervescence ensues which may be watched through low magnification. To be sure that the bubbles consist of CO_2 rather than displaced air, add a drop of 10% barium hydroxide solution. If CO_2 is present a white cloud of barium carbonate will form about the stone. They could be differentiated by x-ray methods.

Calculus composed of apatite is usually found in infected urine. Its color ranges from light yellow to light reddish brown. Occasionally it is colorless. It is hexagonal in crystallization. Physical properties:

Hardness = 5. Specific gravity = 2.95 to 3.10

Optical properties:(12)

O Indices = 1.61 to 1.64

E Indices = 1.61 to 1.64

Index of refraction = 1.55 to 1.59

MAGNESIUM AMMONIUM PHOSPHATE HEXAHYDRATE, $MgNH_4PO_4.6H_2O$

Its mineral name is struvite. It is found in alkaline infected urine. Its color ranges from creamy white to light grey and is very often associated with apatite in calculi. Crystals of magnesium ammonium phosphate hexahydrate may be observed in open cracks in banded or laminated calculi of apatite and also projecting into cavities in porous stones, or some central portion of some apatite. It is orthorhombic-hemimorphic in crystallization. Physical properties:

Hardness = 2. Specific gravity = 1.71

Optical properties:(13)

X = 1.495	Biaxial positive (+)
Y = 1.496	2 V = 37°. Dispersion r<v, strong.
Z = 1.504	

URIC ACID, $C_5H_4N_4O_3$

Uric acid calculi are reddish brown in color and have smooth pebble-like surface. The cross section usually shows a concentric lamination of variable coarseness with radical striation, and with alternating light and dark laminations. Uric acid occurs most often in the pure state but sometimes it occurs with calcium oxalate monohydrate to form calculi or mixed composition. In crystallization uric acid is orthorhombic and has a good cleavage. Physical properties:

Hardness = 2-1/2. Specific gravity = 1.89

Optical properties:(14)

The optical plane is parallel to (001), with X = 1.573

Z = 1.830

CYSTINE, $SCH_2CH(NH_2)-COOH$

Cystine occurs in the pure state but could be found with calcium oxalate monohydrate or apatite. It is usually yellowish white or pearly white in color. It usually consists of porous aggregates of short hexagonal prisms with a compact granular center. Internal growth bands parallel to the external hexagonal crystal faces are usually found in the fragments of cystine calculus. Physical properties:

Hardness = 2. Specific gravity = 2.06

Optical properties:(15)

O = 1.700

E = 1.640

Uniaxial negative (-)

TRICALCIUM PHOSPHATE, $Ca_3(PO_4)_2$

The mineral name is whitlockite. It is greyish white in color and usually contained a small amount of CO_2. It is rhombohedral in crystallization, and has no cleavage. Physical properties:

Hardness = 5. Specific gravity = 3.12

Optical properties:(16)

O = 1.629

E = 1.626

Uniaxial negative.

No sharp line could be drawn easily between "pure", and "mixed" calculi. In the phosphatic calculi, the magnesium ammonium phosphate content varies over the whole range from nearly 0 to 90%. Trace amounts Pb, Fe, Zn, Co, citrate, amino acids, and cholesterol could be incorporated in the calculi from the urine.(17)

CHAPTER IV

THE PRESENT ANALYTICAL APPROACHES AND THEIR INADEQUACIES

The present approaches for the analysis of urinary calculi are (1) by thin section technic, (2) by x-ray diffraction, (3) by optical methods, (4) by chemical methods and (5) by transmission infrared spectra.

THE THIN SECTION TECHNIC

The calculus is sectioned so that the nucleus and laminations could be examined. If the section is thin enough to transmit light it could be studied with polarized light.(18)

This technic is very tedious and requires great skill in sectioning the calculus. Very often the small size of the calculus makes sectioning impossible. The actual identification of the components is difficult. Thus, this method is chiefly used for photographic reproduction, and has not been used as a routine laboratory method.

X-RAY DIFFRACTION

A very small sample is ground to very fine powder, and irradiated with a beam of monochromatic x-rays. The diffracted rays are photographed.(19) There is no doubt about the specificity, and accuracy of this method. But the equipment is expensive and the interpretation requires extensive theoretical knowledge. Thus this method is mainly used for research to determine the exact structure of the crystals.

OPTICAL METHOD

The calculus is fractured and dissected and individual crystals identified by their refractive index. Under a chemical microscope and by immersion of the crystals in a series of fluids of known refractive index the optical sign, axial angle, dispersion, extinction angle, and sign of elongation of the crystals could be measured. This is based on the principle that chemical compounds would form crystals when they pass from the liquid or gaseous state to the solid state. They exhibit characteristic constants and characteristic geometric forms.(20) This method is highly specific and accurate. But it requires a petrographic microscope, and it is hard to master the skill to identify the crystals. This method is used successfully for research, and is not practical for routine laboratory use.

CHEMICAL METHODS

The calculus is ground to fine powder, and analyzed by the following methods:

CHEMICAL METHODS

Table II

Qualitative Test Used for Analysis of Calculi

Substance		Method
Carbonate	1	Add HCl $\rightarrow$ effervescence of CO_2
Calcium oxalate	1	Resorcinol + H_2SO_4 $\rightarrow$ blue green
	2	HCl + MnO_2 $\rightarrow$ gas bubbles
	3	Make HCl solution of stone alkaline with NH_4OH, add acetic acid, examine crystals; to confirm, add H_2SO_4, heat, add $KMnO_4$
	4	Diphenylamine + H_3PO_4 + heat + alcohol $\rightarrow$ blue
	5	HCl solution + saturated sodium acetate to p^H $\rightarrow$ white ppt.
	6	Convert to $CaCO_3$ by heat, add HCl $\rightarrow$ CO_2
Calcium	1	Add oxalic acid after removing calcium oxalate $\rightarrow$ white ppt.
	2	Picrolinate
Magnesium	1	HCl extract + alkali + p-nitrobenzene-azoresorcinol $\rightarrow$ blue color
	2	Remove calcium oxalate and other Ca, add NH_4OH to pH 8, add Na_2HPO_4 $\rightarrow$ $MgNH_4PO_4$ ppt.
	3	Acid extract + quinalizarin + NH_3 $\rightarrow$ blue
	4	Titan yellow
Ammonium	1	Nessler's reaction
	2	Add NaOH $\rightarrow$ odor of NH_3

Table II (continued

Qualitative Test Used for Analysis of Calculi

Substance	Method
Phosphate	1 HNO_3 extract + ammonium molybdate + heat → yellow ppt. 2 Acid molybdate + $SnCl_2$ → blue 3 Acid extract + molybdate + aminonaphtholsulfonic acid → blue
Uric acid	1 Alkaline extract + phosphotungstate → blue 2 Alkaline extract + arsenophosphotungstate → blue 3 Murexide reaction: add NHO_3 evaporate to dryness, add NH_4OH → brilliant purple
Cystine	1 Add NH_4OH + NaCN + sodium nitroprusside → red 2 Evaporate NH_4OH extract on micro slide → hexagonal plates 3 Add HCl + NaCN + 1,2-naphthoquinone 4-sulfonate + Na_2SO_3 + HaOH → red brown, turning deep red on adding $Na_2S_2O_4$ in HaOH 4 Add NaOH, heat, lead acetate, heat → PbS ppt. (black)
Xanthine	1 Murexide reaction: add NHO_3 evaporate, add NaOH → orange, turning red with heat 2 Ehrlich's diazo reaction 3 Add NaOH to residue from murexide test → red; add H_2O → yellow, which when evaporated → red-violet

Table II (continued)

Qualitative Test Used for Analysis of Calculi

Substance		Method
Indigo	1	Reduce to leuco form, reoxidize to indigo
	2	$CHCl_3$ extract is blue
Urostealith	1	Evaporate ether or $CHCl_3$ extract, stain with Sudan III
Sulfonamides	1	Add HCl + $NaNO_2$+ N-(1-naphthyl)-ethylenediamine .2HCl → pink or magenta
Cholesterol	1	Liebermann-Burchard color reaction
Fibrin	1	Millon's reagent + heat → red ppt.

(21)

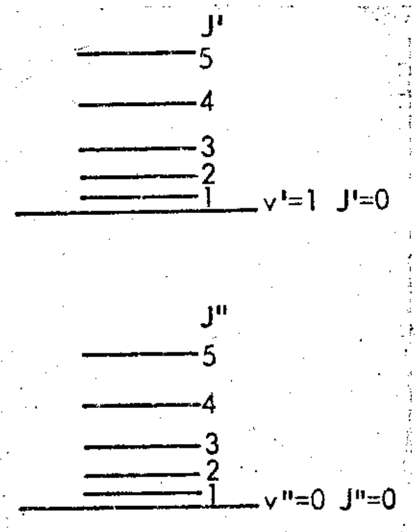
These qualitative chemical analysis methods are widely used because of their simplicity. They are not very accurate. Often constituents of urinary calculi identified by these chemical methods are found to be non-existent when done by physical methods. On the other hand many constituents are identifiable by physical methods but not by the chemical methods.

The following reasons may be adduced in explanation of this situation: (1) Confusion exists as to the exact nature of the reactions which take place in the procedures used in qualitative chemical tests. (2) Interfering organic substances of unknown composition may invalidate these reactions. (3) The complex and commonly admixed nature of the substances occuring in calculi is not amenable to resolution by chemical methods alone. (4) The small size of many calculi makes complete chemical examination impossible.(22)

INFRARED ABSORPTION

Infrared spectra originate in the transitions between two vibrational levels of the molecules in the electronic ground state and are usually observed as absorption spectra in the infrared region, which extends from 12,500 to 50 cm^{-1}. The ordinary infrared region extends from 4000 to 667 cm^{-1}.

Since energy is quantized, energy levels can be indicated by integral values of a quantum number v. Therefore if the lowest level is assigned a value of v = 0, the next higher level is v = 1. The fundamental vibrational energy change could be a jump from v = 0 to v = 1. The fundamental vibrational absorption band is the result of the simultaneous changes in the rotational and vibrational energy of the molecule. In the following figure the quantized rotational energy level is designated as J.



(23)

Figure 1. A vibrational-rotational energy level diagram.

When an energy transition occurs the change in quantum number can be written as

$$\Delta v = v' - V'' = 1 - 0 = + 1$$

$$\Delta v = + 1$$

v' represents a higher energy state than v''. The changes in rotational quantum number associated with these vibrational energy changes in vibrational-rotational infrared bands are

$$J' - J'' = \Delta J = 0, + 1.$$

Then the vibrational quantum number change is

$$\Delta v = + 2$$

and the rotational quantum number changes are again

$$\Delta J = 0, + 1$$

By Hooke's law the vibrational frequency v (cm^{-1}) of the simple diatomic molecule A--B is

$$v = \frac{1}{2\pi c}\left(\frac{f}{u}\right)^{1/2}$$

where c is the velocity of light, f is the force constant of the bond and u is the reduced mass of the system, as defined by

$$u = \frac{m_A \cdot m_B}{m_A \; m_B}$$

where m_A and m_B are the individual masses of A and B.(24)

In order for a vibrational mode to appear in the infrared spectrum, that is to be "infrared active" and to result in absorption of the energy from incident radiation, it is essential that there be a change in the dipole moment of the molecule during the vibration. The two fundamental vibrations for the molecules are (1) stretching, where the atoms stay inthe same bond axis, but there is an increase or decrease in the distance between the two atoms, (2) bending, where the atom changes position in relation to the original bond axis.

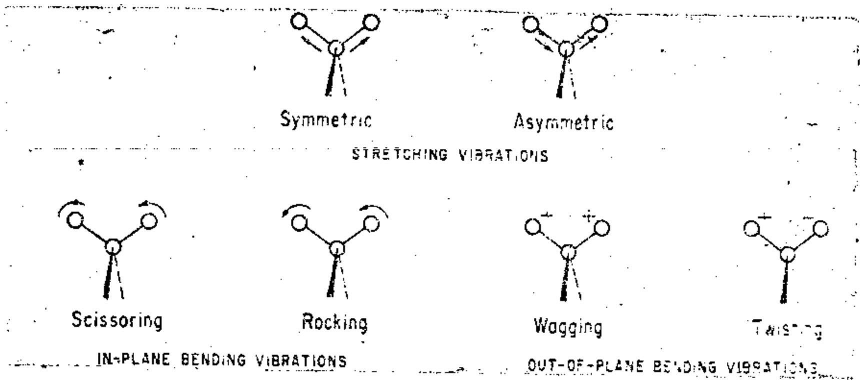


Figure 2. Vibrations of a group of atoms (+ and - signify vibrations perpendicular to the plane of the paper).(25)

The number of normal modes of vibration of a nonlinear molecule with more than four atoms is equal to 3n - 6 where n is the number of atoms in the molecule.

The sample is prepared by intimately mixing 1 mg of finely ground compound to be tested with 250 mg. of dry potassium bromide and compressing into a disk under vacuum for 2 to 3 minutes at 20,000 to 22,000 p.s.i.

This technic is very specific and reproducible. But in subjecting the sample to a pressure of 20,000 to 22,000 p.s.i. there is a possibility of altering the crystal structure, and isomerization or polymerization could occur. This results in a distorted spectrum.

Running the spectrum by attenuated internal reflection has the advantage that making the KBr disk is not required. Buying the press, and the oven for keeping the KBr dry are eliminated. The preparation of the sample is very much easier. Comparison of the spectra run by the two technics shows that those spectra done by attenuated internal reflection have a complete absence of interference fringes which could be a source of error. So the attenuated total reflection method is more practical to be used routinely.

CHAPTER V

ATTENUATED TOTAL REFLECTION, ATR

When a sample which selectively absorbs radiation is placed in contact with the reflecting surface of a KRS—5 crystal the beam will lose energy at those wavelengths where the material absorbs owing to an interaction with the penetrating beam. This attenuated radiation could give rise to an absorption spectrum plotted as a function of wavelength which is characteristic of the sample.

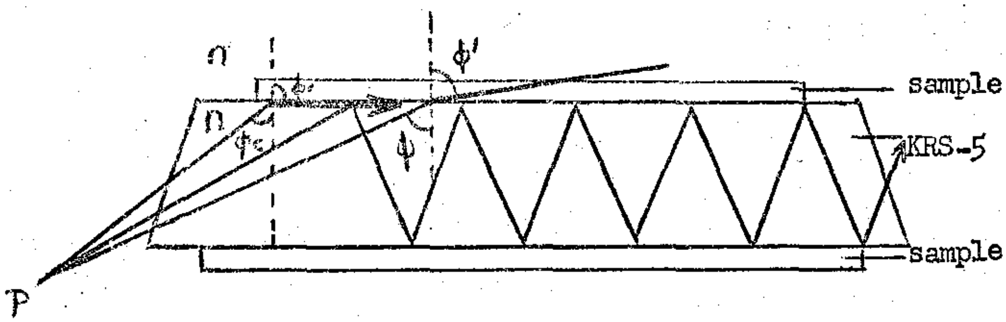


Figure 3. Attenuated Total Reflection

Figure 3 shows two rays in the KRS—5 of index n striking the surface of the sample of index n', where n > n'. From Snell's law,

$$\sin \emptyset' = \frac{n}{n'} \sin \emptyset$$

Since n/n' is greater than unity, sin Ø' is larger than sin Ø and evidently equals unity (ie, Ø' = 90°). The critical angle, Øc is the angle of incidence for which the refracted ray emerges tangent to the surface.(26) Since the angle of incidence is greater than the critical angle, the sine of the angle of refraction, as computed by Snell's law, is greater than unity, and each ray will not enter the sample, but is totally internally reflected at the boundary surface. Likewise, when the ray reaches the opposite boundary of the KRS—5 and the sample it is reflected back again. The KRS—5 crystal used is roughly 50 x 20 x 2 mm, with the 45° angle of incidence giving approximately 25 reflections. By means of this technic many bands of weak intensity could be picked up. The reflectance spectra show strong resemblance to the transmission spectra. This principle could apply to any spectral region, but it is most useful in the infrared where thin layers of sample are often required.

The depth of penetration which ranges from a fraction of a wavelength up to several wavelengths is a function of (1) the wavelength of light, (2) the refractive index of both the reflector and sample, and (3) the angle of incident radiation. Figure 4 shows that the penetration increase most rapidly when the angle of incidence at the interface between the sample and prism is very near the critical angle. When the angle of incidence is greater than the critical angle nearly all the energy goes into the sample.

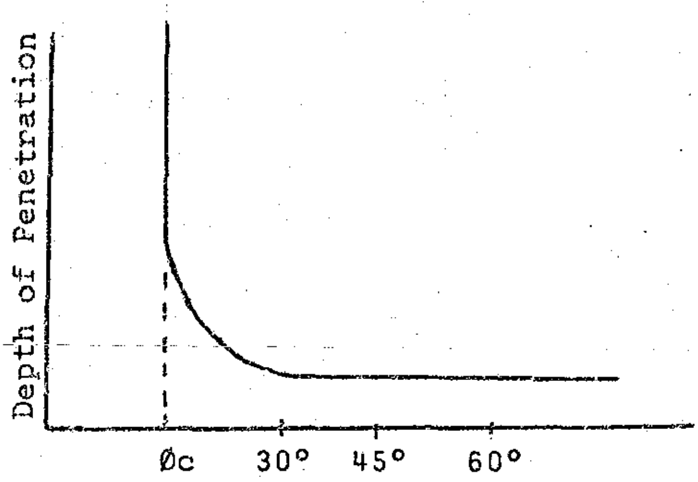


Figure 4. Depth of Penetration vs Angle of Incidence.

Reflectance spectroscopy as an analytical tool has been used for films, paper, paint, fibers, fabrics, foams, minerals, glass and inorganics in general.

CHAPTER VI

INSTRUMENTATION

The instruments used were the Wilks Scientific Corporation Model 12 Double Beam Attachment and the Perkin-Elmer Spectrophotometer 337.

Being a double beam spectrophotometer it has two equivalent beams taken from the source. By means of a rotating mirror, and a light interrupter which is a half of a complete circular mirror, each beam traverses the monochromator detector system on alternating cycles. In the optical null method, a signal results when the two beams are unbalanced. The amplifier is tuned to chop frequency of the light beam. Signals activates a servo mechanism which moves an optical wedge or shutter comb that is mounted in the path of the reference beam, and so reducing its energy until both beams are again balanced. The optical attenuator is linked mechanically to the recorder pen which is moved across the chart paper as the equilibrium position is sought. The tracing of the pen in the recorder is the relative transmittance of the sample.(27)

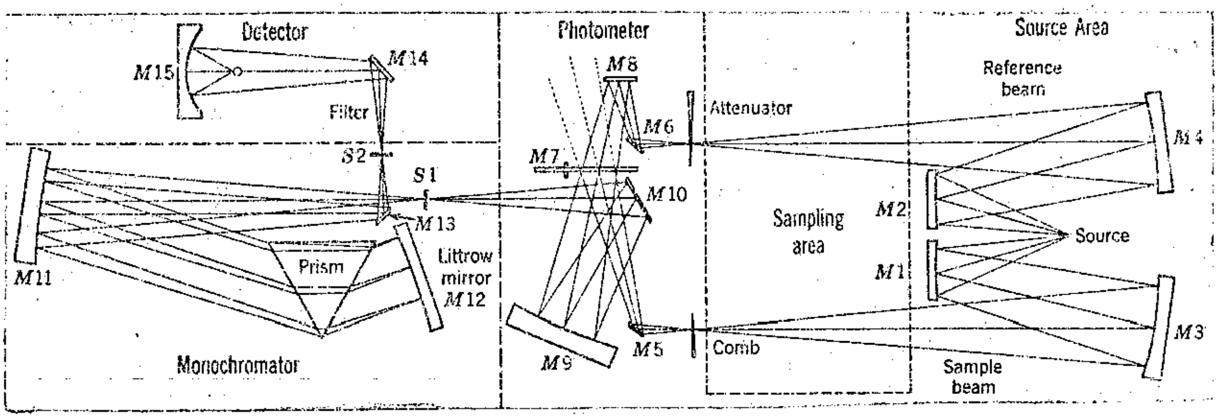


Figure 5. Optical system of double-beam infrared spectrophotometer.(28)

The Wilks Scientific Corporation Model 12 Double Beam Attachment designed for double-beam spectrometers is placed into the cell compartment of the Perkin-Elmer Spectrophotometer 337. This Model consists of a dual optical system, and each unit track could be mounted and adjustable to fit the different beam separation of the Perkin-Elmer Spectrophotometer. Light from the radiation source is reflected from mirror M_1 to mirror M_2 and then to the entrance face of the KRS——5 crystal. Emergent light from the exit face of the crystal is re-imaged on the entrance part of the spectrophotometer by mirrors, M_3, and M_4.(29)

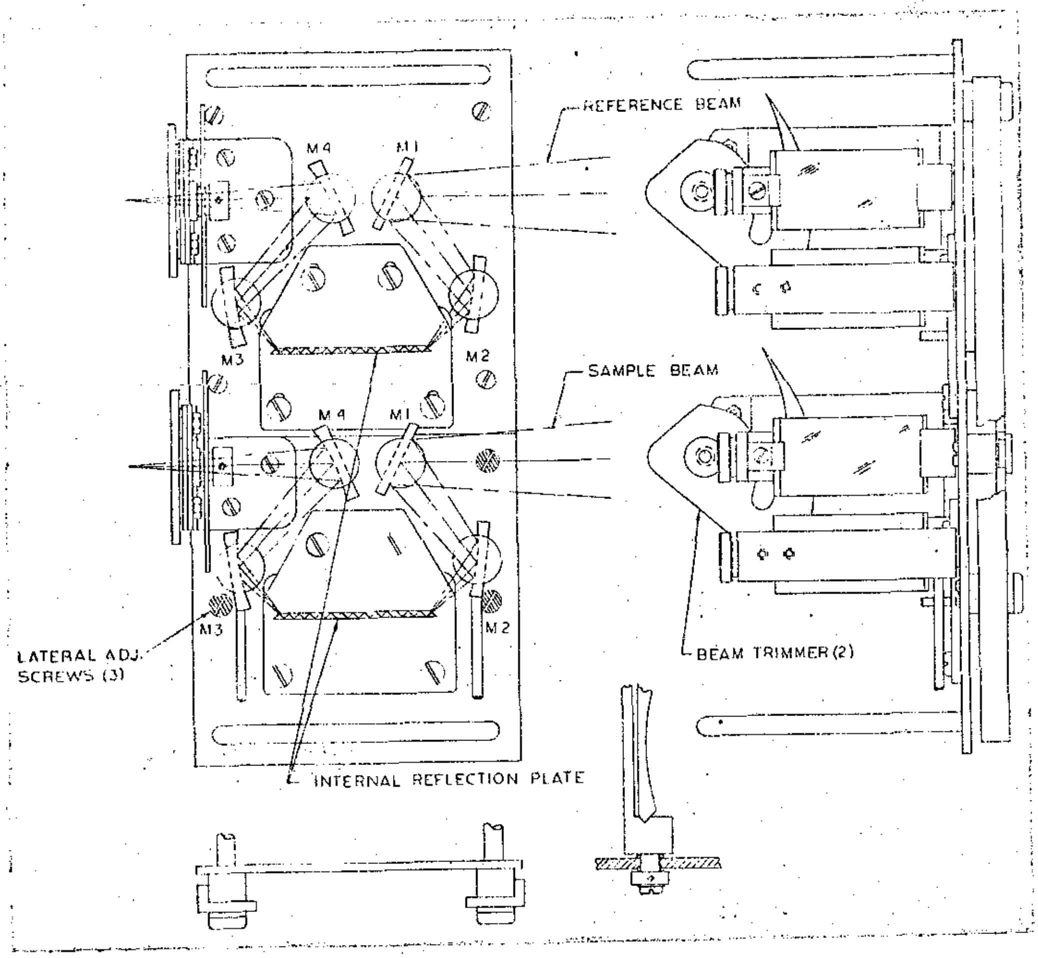


Figure 6. Working Diagram of Model 12 Wilks Scientific Corporation Double Beam Attachment(30)

Thallous-bromide-iodide, KRS—5 is chosen to be used as the crystal because it shows the most all-round usefulness in internal reflection spectroscopy. It is tough enough to stand pressure, and is able to resist the effects of cleaning solvents as cold water. Its reflective index is high enough to produce good spectra. It could be scratched easily and should be handled with care.

CHAPTER VII

EXPERIMENTAL AND DISCUSSION

The experimental work consists of (1) the development of a technic, (2) running spectra of known compounds both by transmission IR and ATR, and (3) applying the developed technic to analyze a urinary calculus.

The known compounds to be run are in the form of either crystal or powder. They can be applied directly on both sides of the KRS——5 crystal. The difficulty of this technic is getting even thickness. The easiest technic is to spread the sample evenly on the sticky side of the scotch tape which is cut to fit the size of the KRS——5 crystal. Then apply the side of the scotch tape where the sample is on both sides of the crystal.

It is important that there is a good contact between the sample and the crystal. Uneven thickness will give poor contact which will result in the loss of absorption.

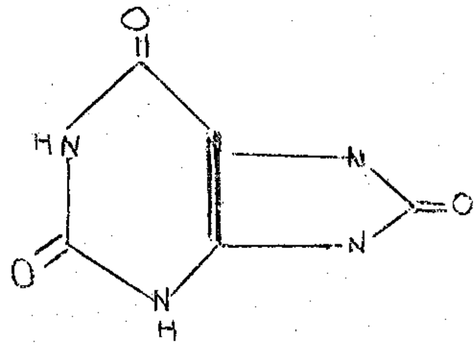
The most common components of urinary calculi are uric acid $C_5H_4N_4O_3$, Calcium Oxalate Monohydrate $CaC_2O_4.H_2O$, Tricalcium Phosphate $Ca_3(PO_4)_2$, Magnesium Phosphate $MgHPO_4$, Calcium Hydrogen Phosphate $CaHPO_4$, Indigo $C_{16}H_{10}N_2O_2$, and cystine $SCH_2CH(NH_2)$-COOH. ATR and transmission IR spectra of these compounds are made individually first, and then the spectra of different combinations of them are made.

The urinary calculus is about 0.5 by 0.4 by 0.6 cm. The surface is smooth and flattened pabblelike. It is dark brown in color. Being relatively soft it could easily be crushed. In cross section the nucleus could be seen with laminations around it. This calculus is ground to fine powder by which transmission IR and ATR spectra are run.

The spectra of the transmission IR and ATR of the urinary calculus match consistently with those of 50% uric acid and 50% tricalcium phosphate. See Figure 7 and 8.

$Ca_3(PO_4)_2$

Tricalcium Phosphate



Uric Acid

TABLE III

Absorption of functional groups of uric acid and tricalcium phosphate

Absorption	Functional Group
3500—3000 strong	-NH- amine of uric acid.
1680 strong	-C=O- Carbonyl group of uric acid.
1120—1020 strong	PO_4^{3-} Phosphate of tricalcium phosphate
990 moderate	PO_4^{3-} Phosphate of tricalcium phosphate

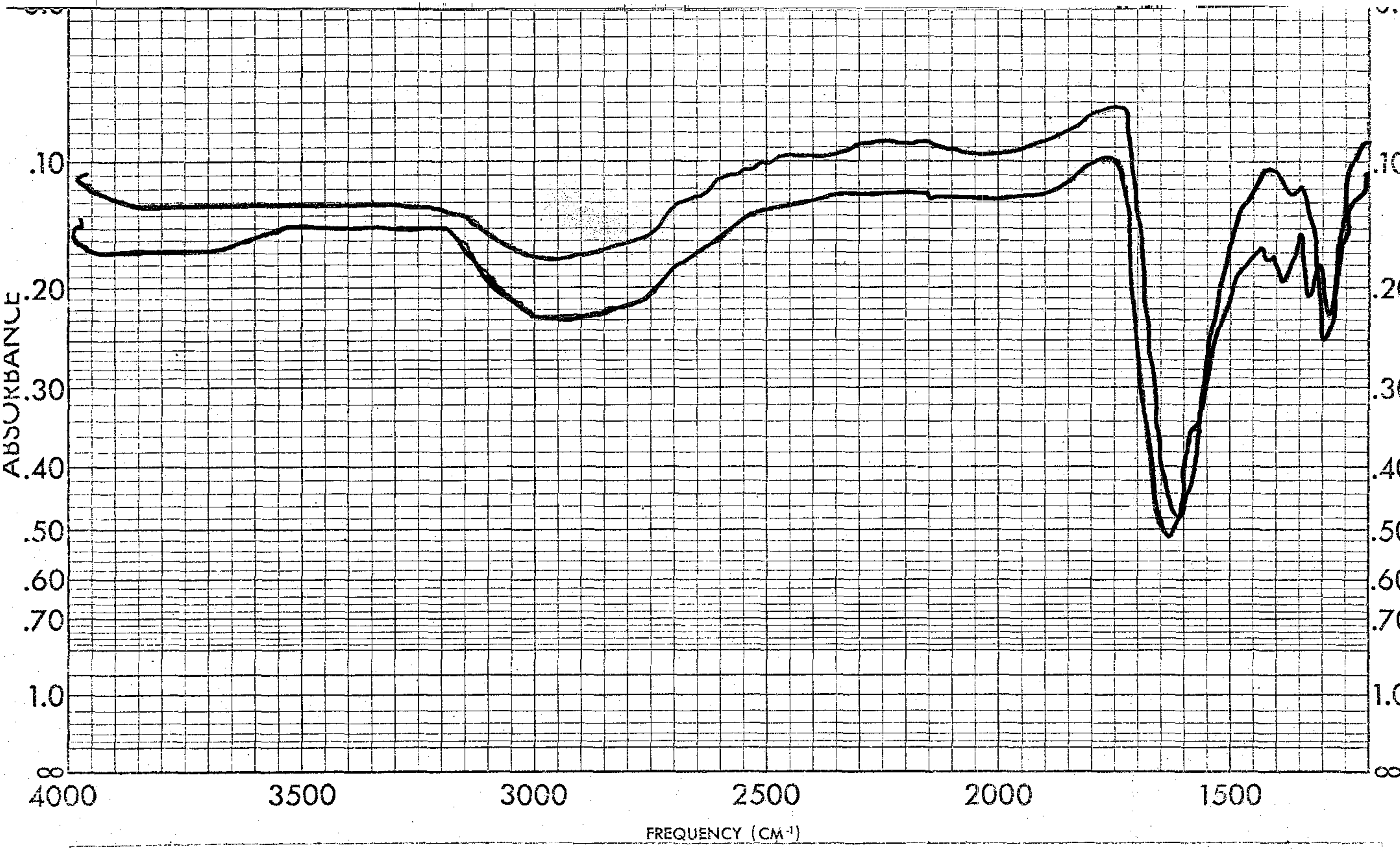


Figure 7. Spectrum of 50% uric acid, $C_5H_4N_4O_3$, and 50% tricalcium phosphate, $Ca_3(PO_4)_2$ (red) and a urinary calculus (blue) by ATR.

PERKIN-ELMER ®

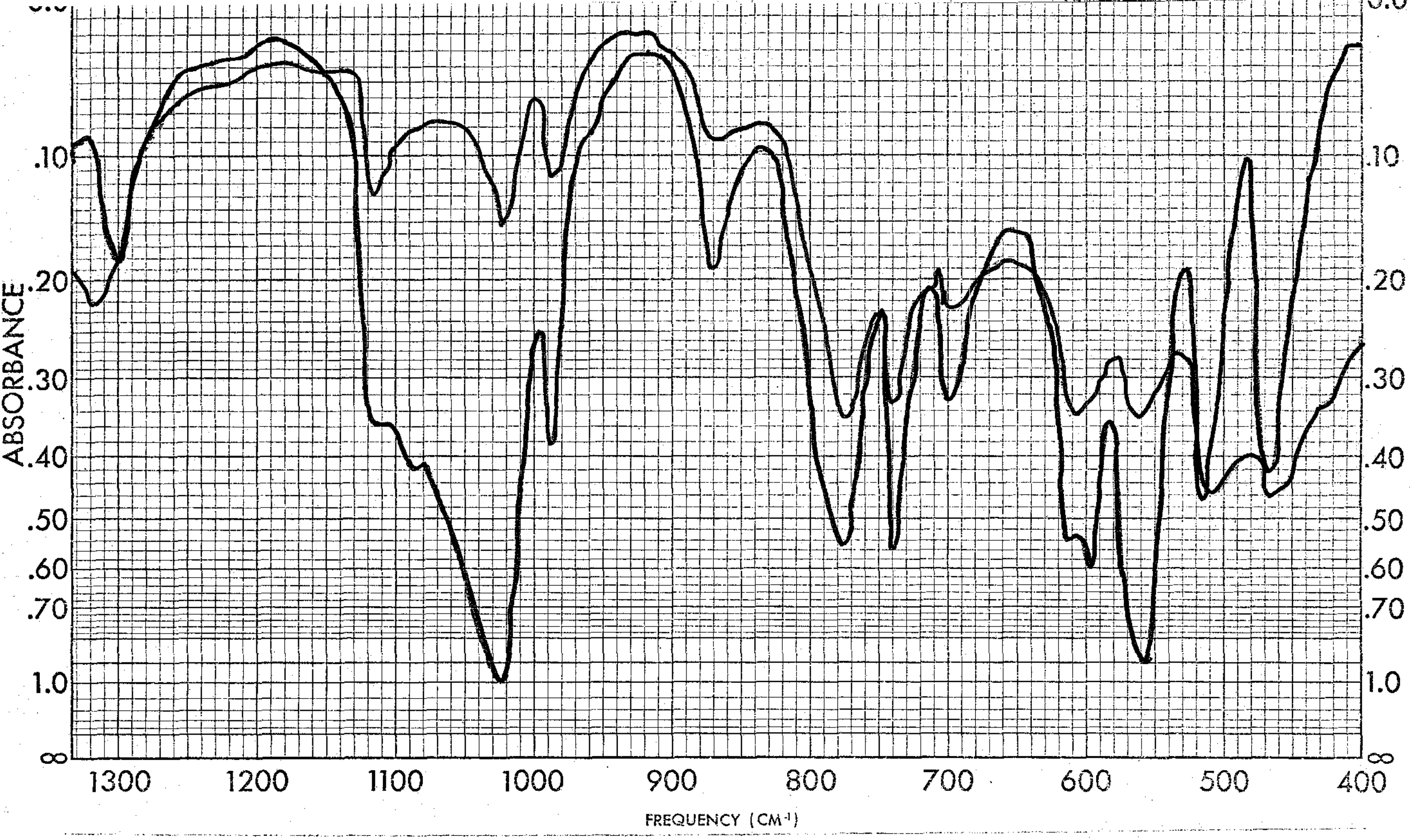


Figure 7. Spectrum of 50% uric acid, $C_5H_4N_4O_3$, and 50% tricalcium phosphate, $Ca_3(PO_4)_2$ (red) and a urinary calculus (blue) by ATR.

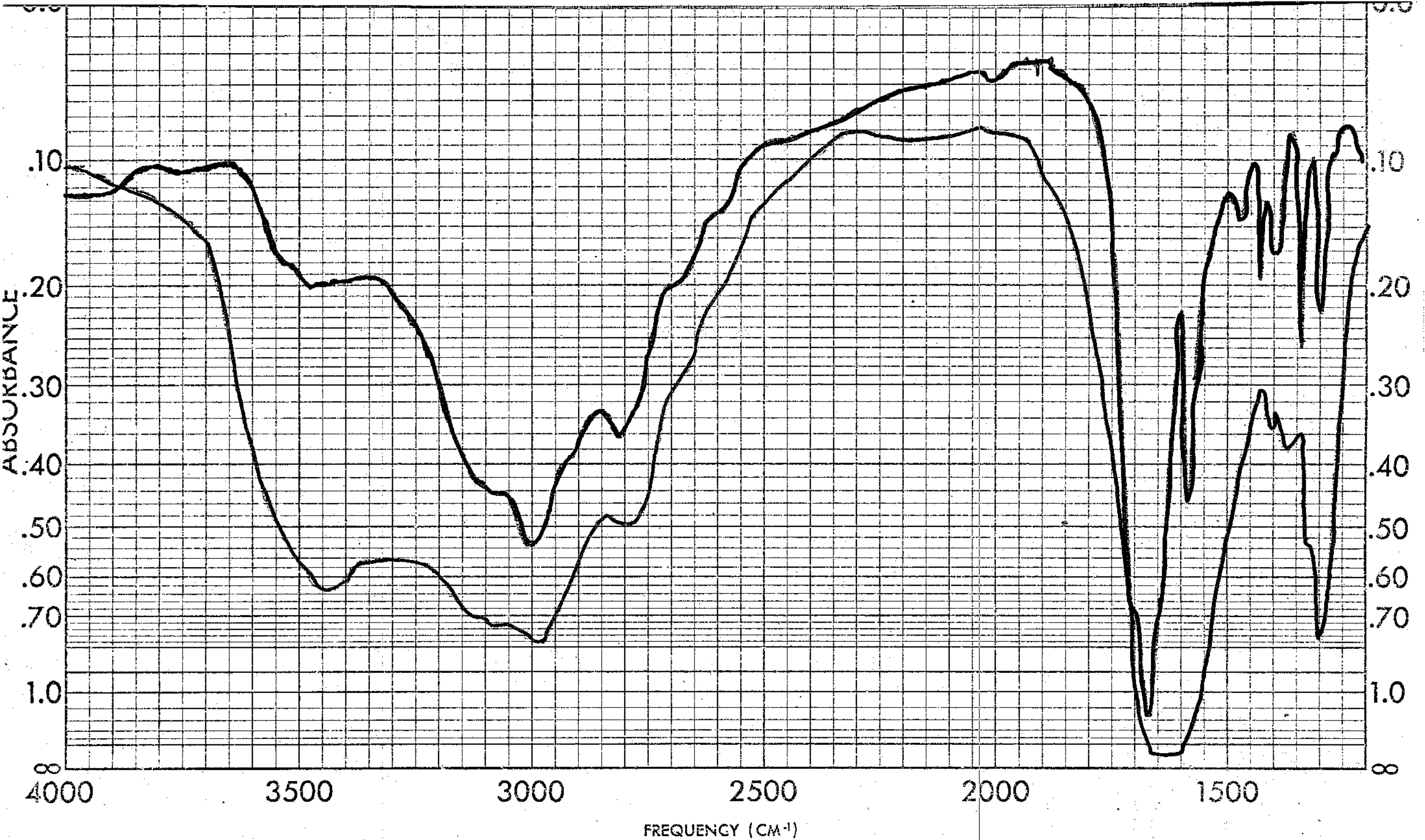


Figure 8. Spectrum of 50% uric acid, $C_5H_4N_4O_3$, and 50% tricalcium phosphate, $Ca_3(PO_4)_2$ (red) and a urinary calculus (blue) by transmission I.R.

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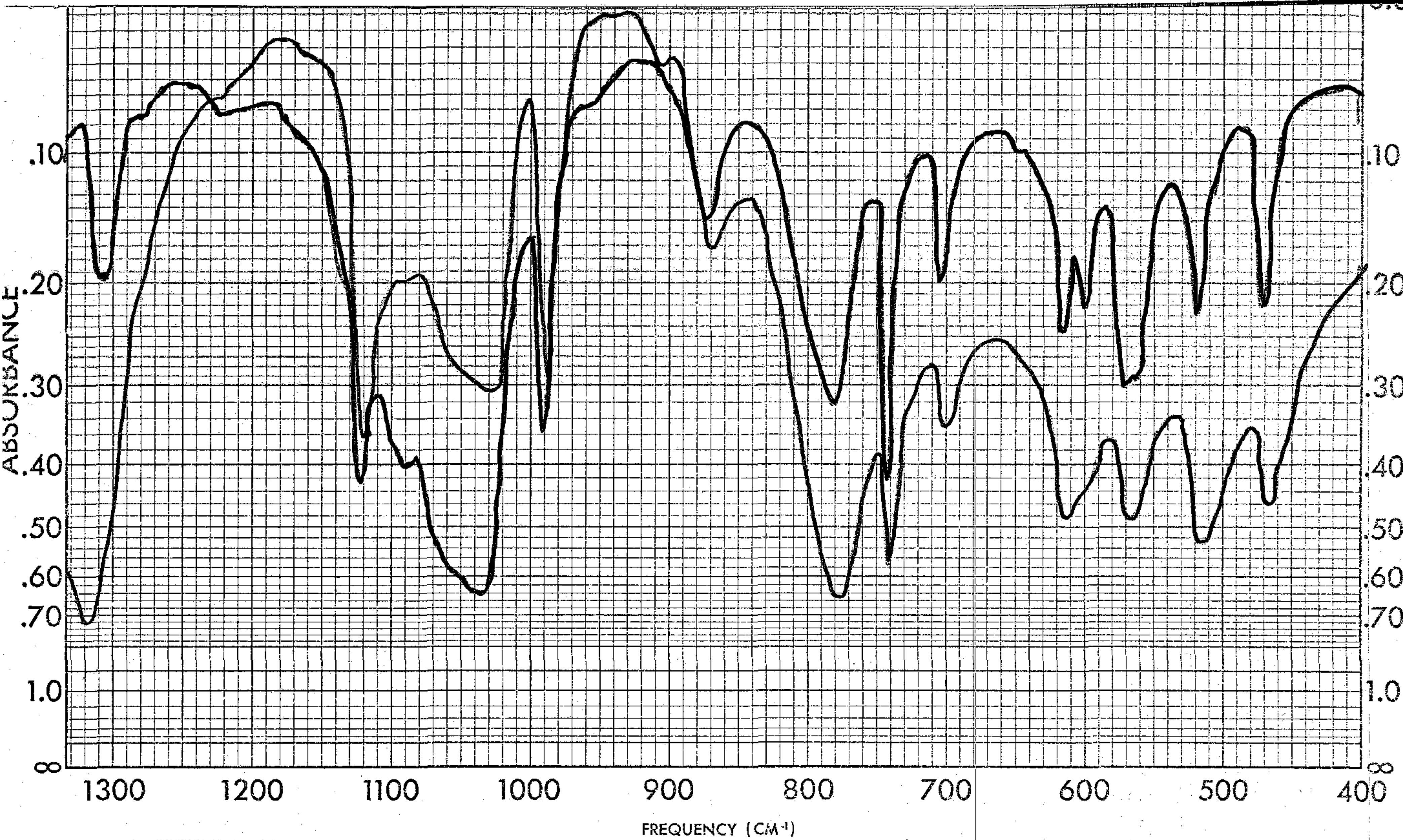

Figure 8. Spectrum of 50% uric acid, $C_5H_4N_4O_3$ and 50% tricalcium phosphate, $Ca_3(PO_4)_2$ (red) and a urinary calculus (blue) by transmission I.R.

The absorption bands of the finger-print region are characteristics of uric acid and tricalcium phosphate.

Chemical tests show that uric acid, calcium, and phosphate are present in the calculus.

Having good infrared absorptivity urinary calculi give rise to distinct characteristic bands. When they are ground to fine powder getting good contact between the sample and the KRS—5 crystal could be done by applying more pressure onto the plate. If there is not sufficient difference between the indices of the plate and the sample, a "distorted" curve will result. This distorted band will show a sharp break or sometimes an upward inflection at its short wavelength and while the long wavelength side will be broadened especially at the top of the band. This distorted band could be corrected by using a higher index material such as germanium in place of KRS—5, or using a greater angle of incidence.

ATR is a fairly reliable semi-quantitative technic since the depth of penetration by the IR beam into the sample is uniform. The biggest problem is getting reproducible contact between the sample and the crystal. As it is impossible to make KBr disks of the same thickness transmission IR cannot be used for quantitative analysis.(31)

One great advantage of ATR over the chemical methods is that very small quantity of sample is required. Most urinary calculi are too small to run chemical tests on.

Because of competition and the high cost of labor medical laboratories are looking for faster and less expensive methods for running tests. The ATR technic eliminates the cost of reagents, and it is much less time consuming.

CHAPTER VIII

CONCLUSION

In this research a new technic for the analysis of urinary calculi is developed. In the appendix are the ATR spectra of the possible components of urinary calculi to serve as an atlas. The transmission IR spectra are for comparison.

ATR differs from infrared transmission spectrometry in that the infrared beam is reflected from the sample into the slit of the spectrophotometer instead of passing straight through the sample.

It is a relatively new technic, and it is found to be a useful analytical tool for urinary calculi. As more research is done on it, it will be used to a greater extent in the future because of its advantages over other methods.

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APPENDIX

LIST OF SPECTRA BY TRANSMISSION I.R.

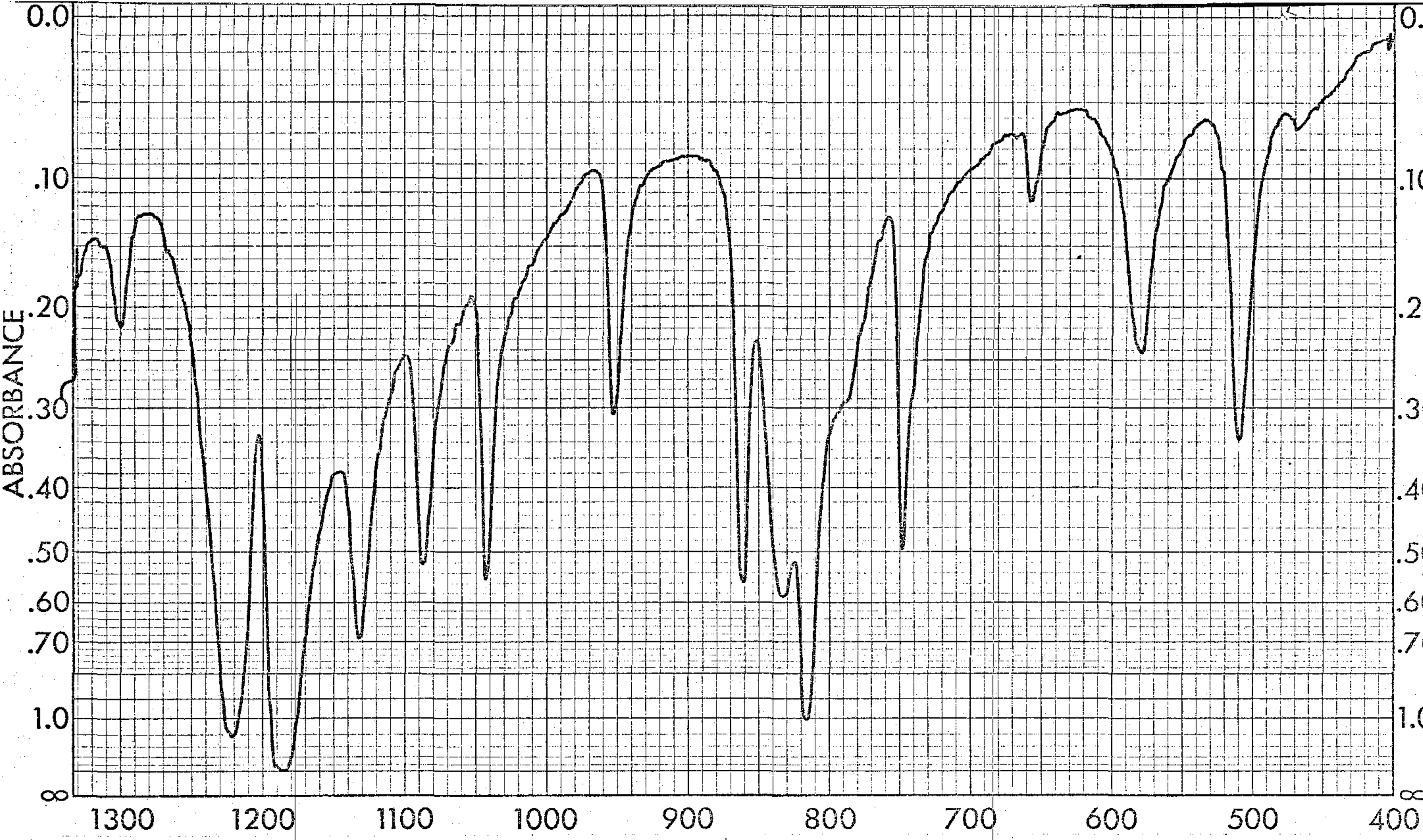
NAMES OF COMPOUND/COMPOUNDS SPECTRUM NO.

NAMES OF COMPOUND/COMPOUNDS	SPECTRUM NO.
25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate, $MgHPO_4$.	45
50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$. .	46
50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, and 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$	47
25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Tri-calcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium Phosphate, $MgHPO_4$.	48
50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, and 25% Magnesium Phosphate, $MgHPO_4$.	49
50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Phosphate, $MgHPO_4$, and 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$	50
50% Magnesium Phosphate, $MgHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Hydrogen Phosphate, $CaHPO_4$	51

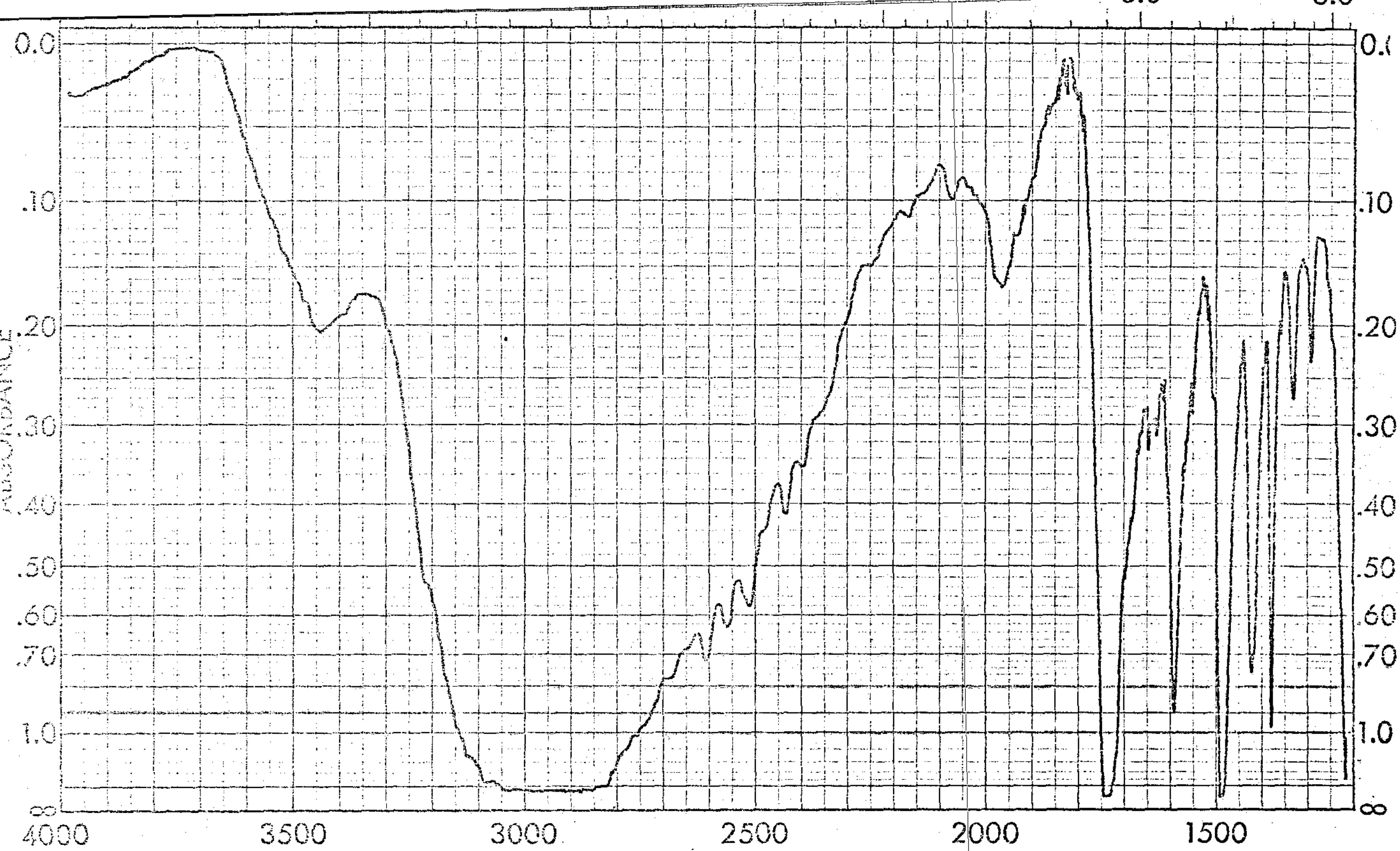
NAMES OF COMPOUND/COMPOUNDS SPECTRUM NO.

LIST OF SPECTRA BY ATTENUATED TOTAL REFLECTION

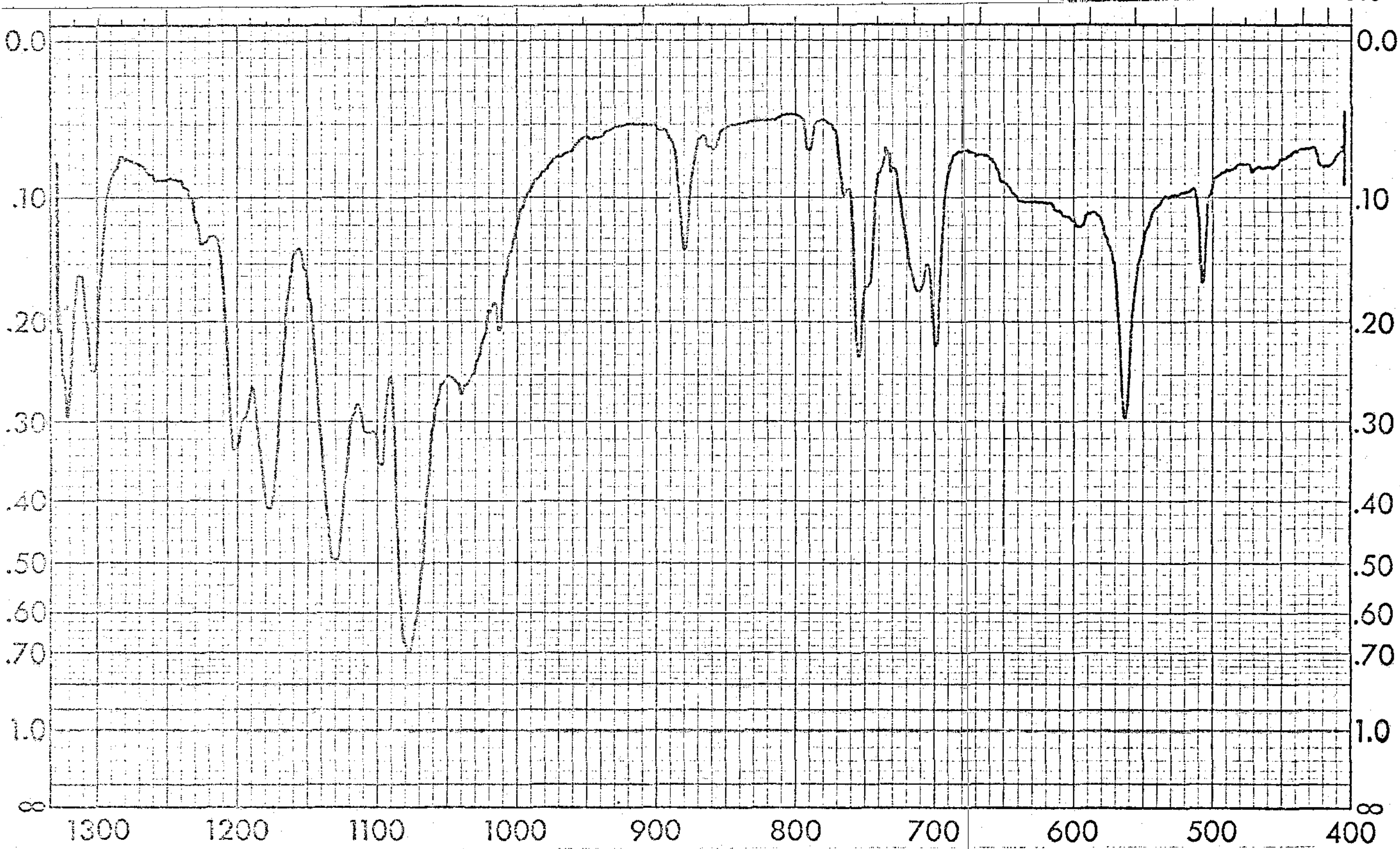
NAMES OF COMPOUND/COMPOUNDS	SPECTRUM NO.
50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$. . . .	105
50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, and 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$	106
25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium Phosphate, $MgHPO_4$.	107
50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, and 25% Magnesium Phosphate, $MgHPO_4$.	108
50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Phosphate, $MgHPO_4$, and 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$	109
50% Magnesium Phosphate, $MgHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Hydrogen Phosphate, $CaHPO_4$	110
25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$. . .	111



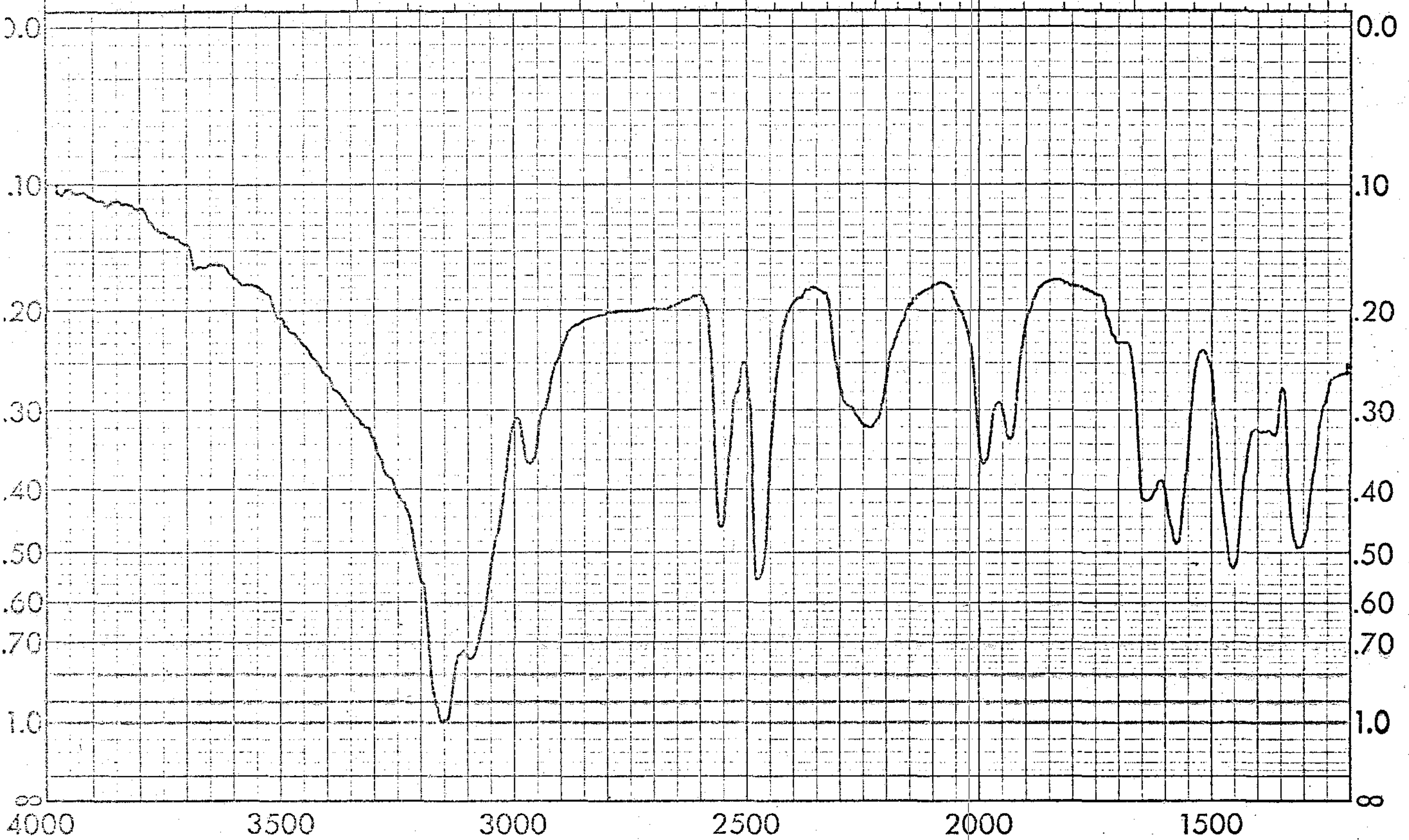
Spectrum No. 1: Cystine, $SCH_2CH(NH_2)$-COOH By Transmission I.R.



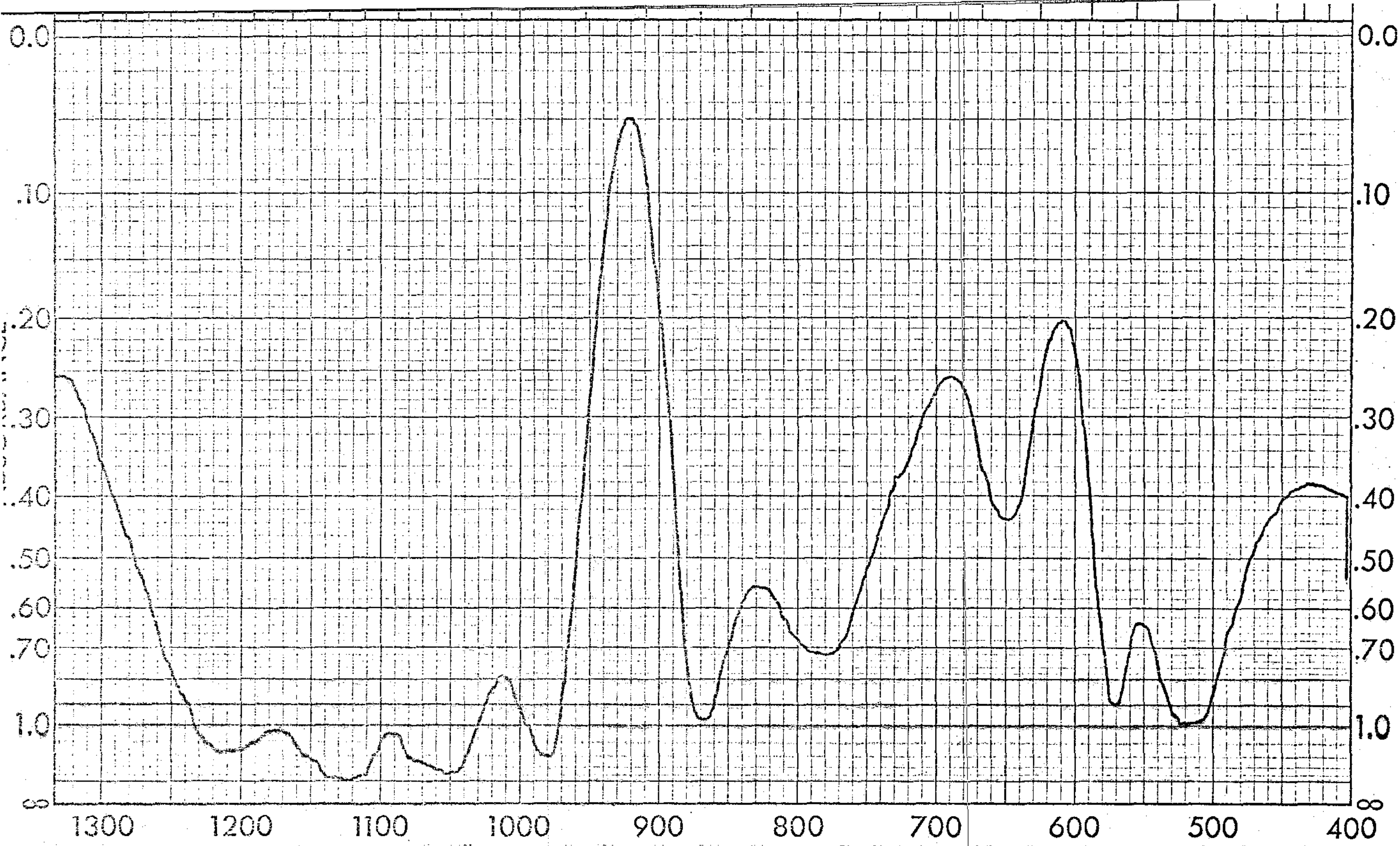
Spectrum No. 1: Cystine, $SCH_2CH(NH_2)-COOH$ By Transmission I. R.



Spectrum No. 2: Indigo, $C_{16}H_{10}N_2O_2$ By Transmission I.R.

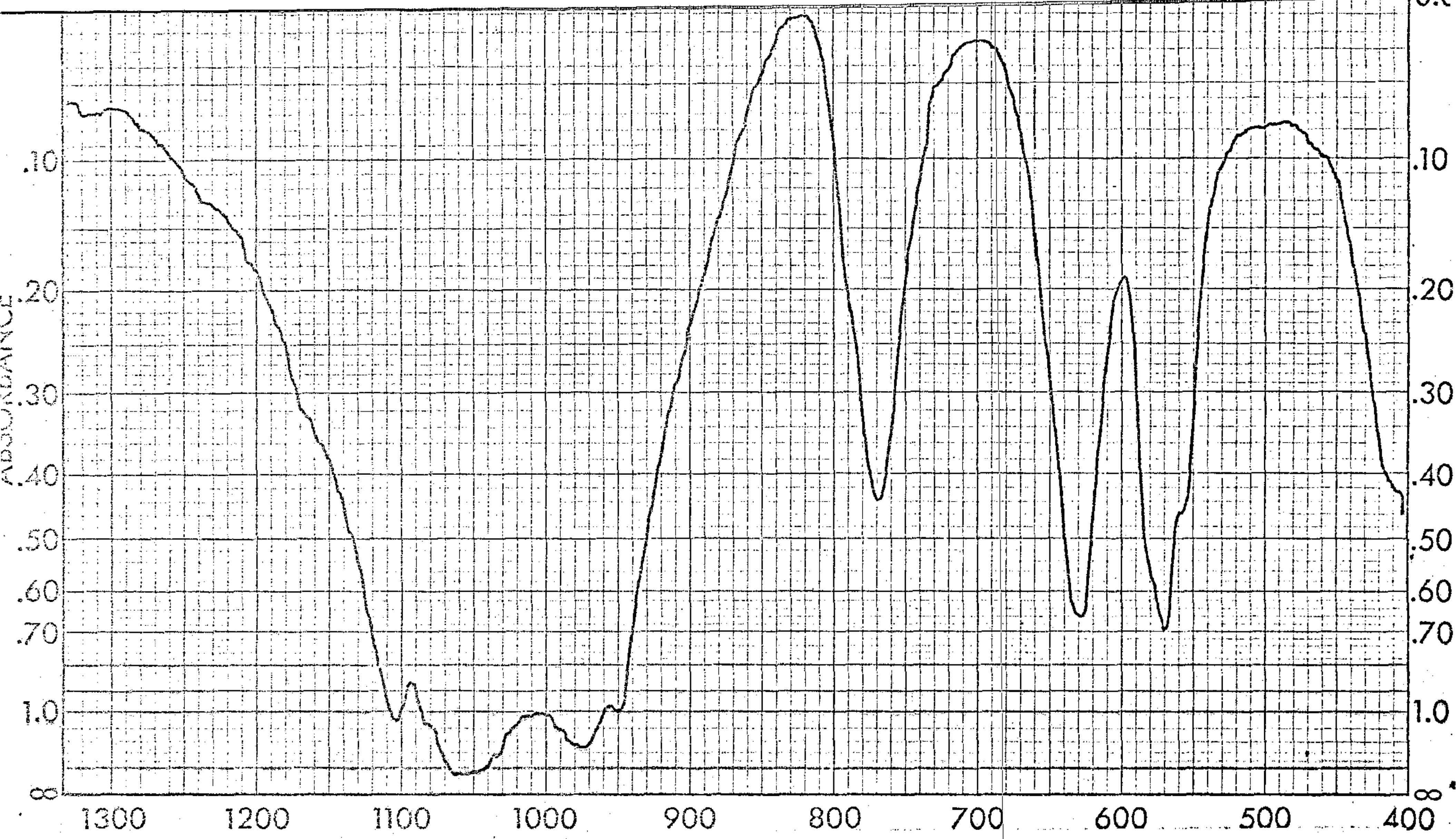


Spectrum No. 2: Indigo, $C_{16}H_{10}N_2O_2$ By Transmission I.R.



Spectrum No. 3: Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.

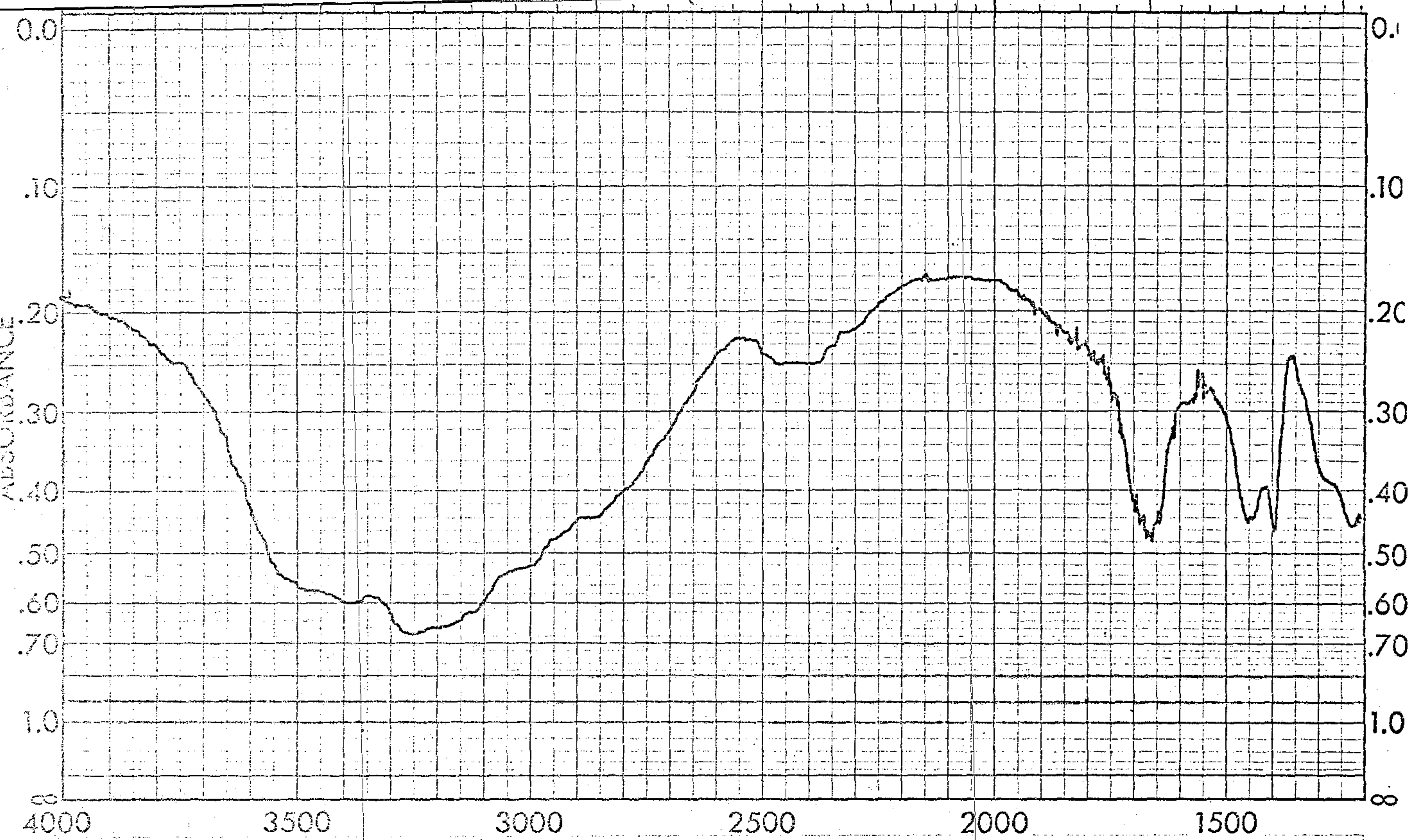
Spectrum No. 3: Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission. I. R.



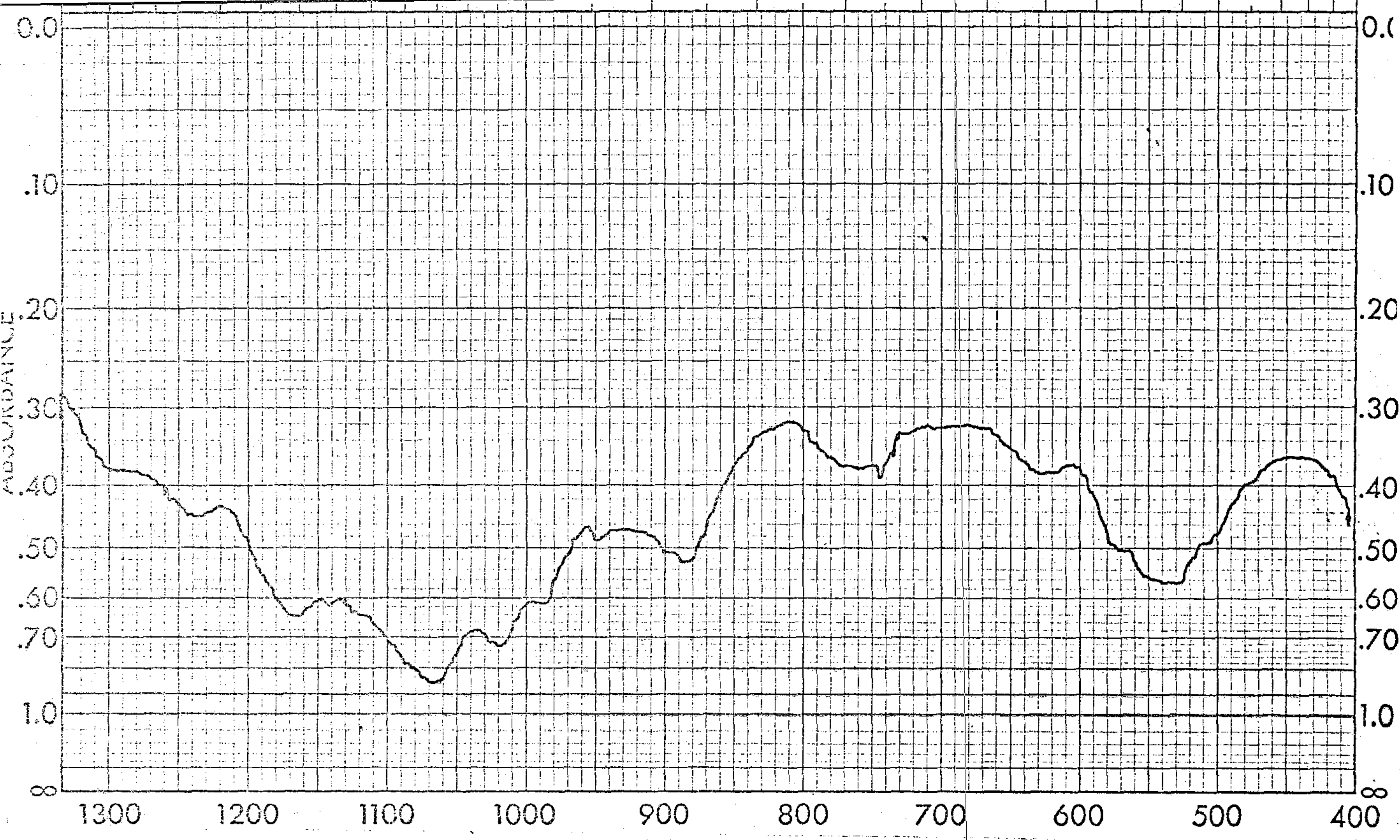
Spectrum No. 4: Magnesium Ammonium Phosphate Hexahydrate,

$MgNH_4PO_4 \cdot 6H_2O$ By Transmission I.R.

Spectrum No. 4: Magnesium Ammonium Phosphate Hexahydrate, $MgNH_4PO_4 \cdot 6H_2O$ By Transmission I. R.



Spectrum No. 5: Magnesium Ammonium Phosphate, $MgNH_4PO_4$ By Transmission.I.R.



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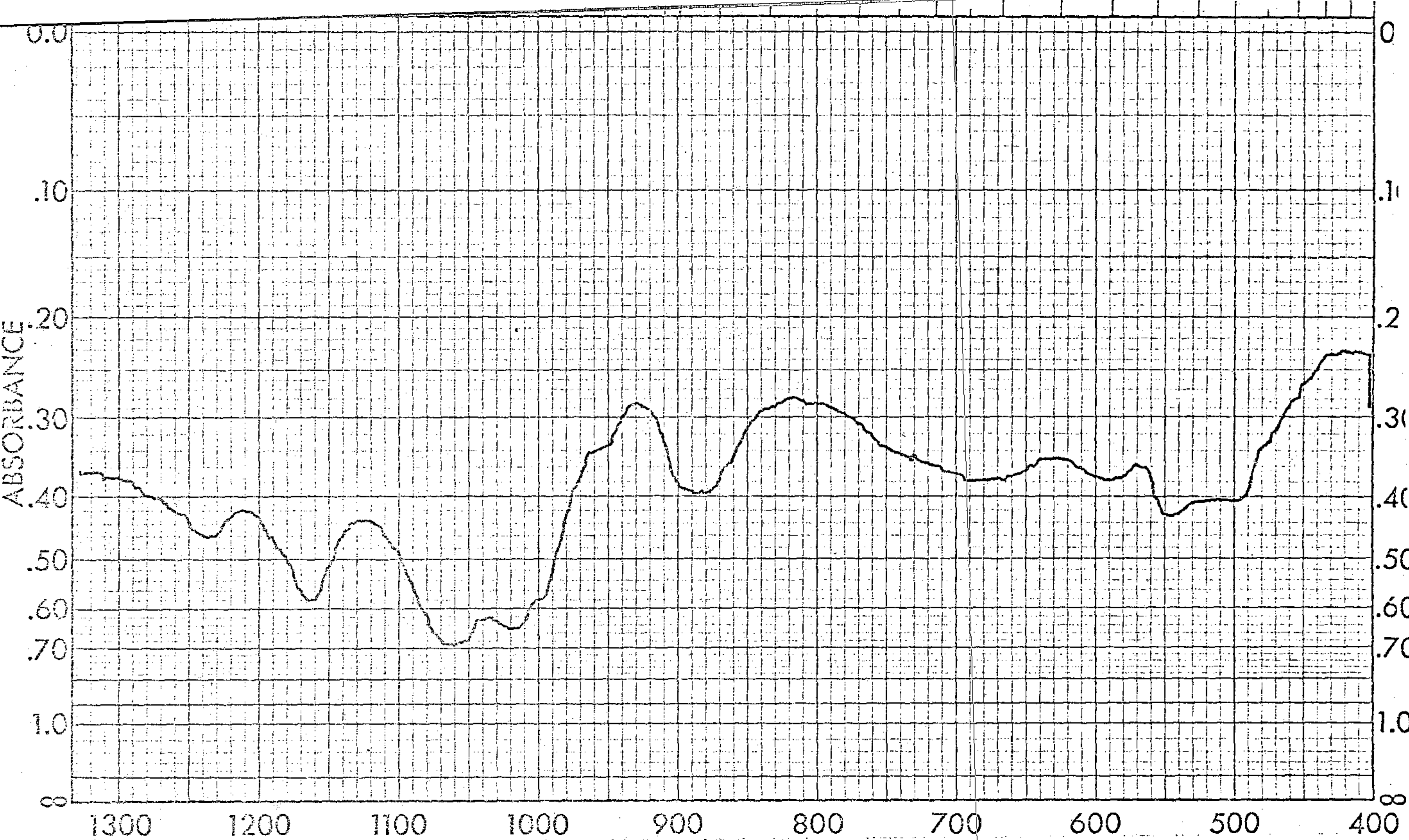
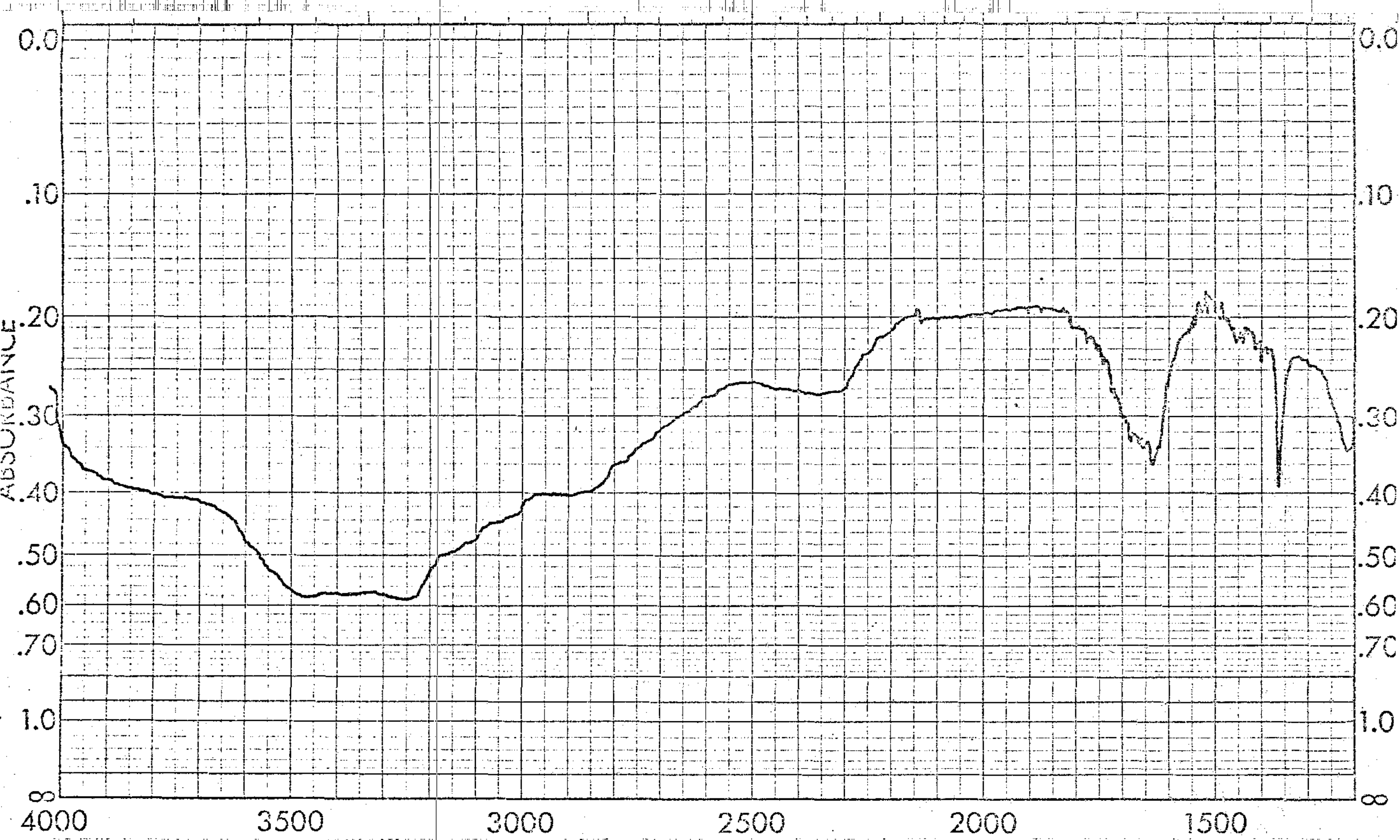
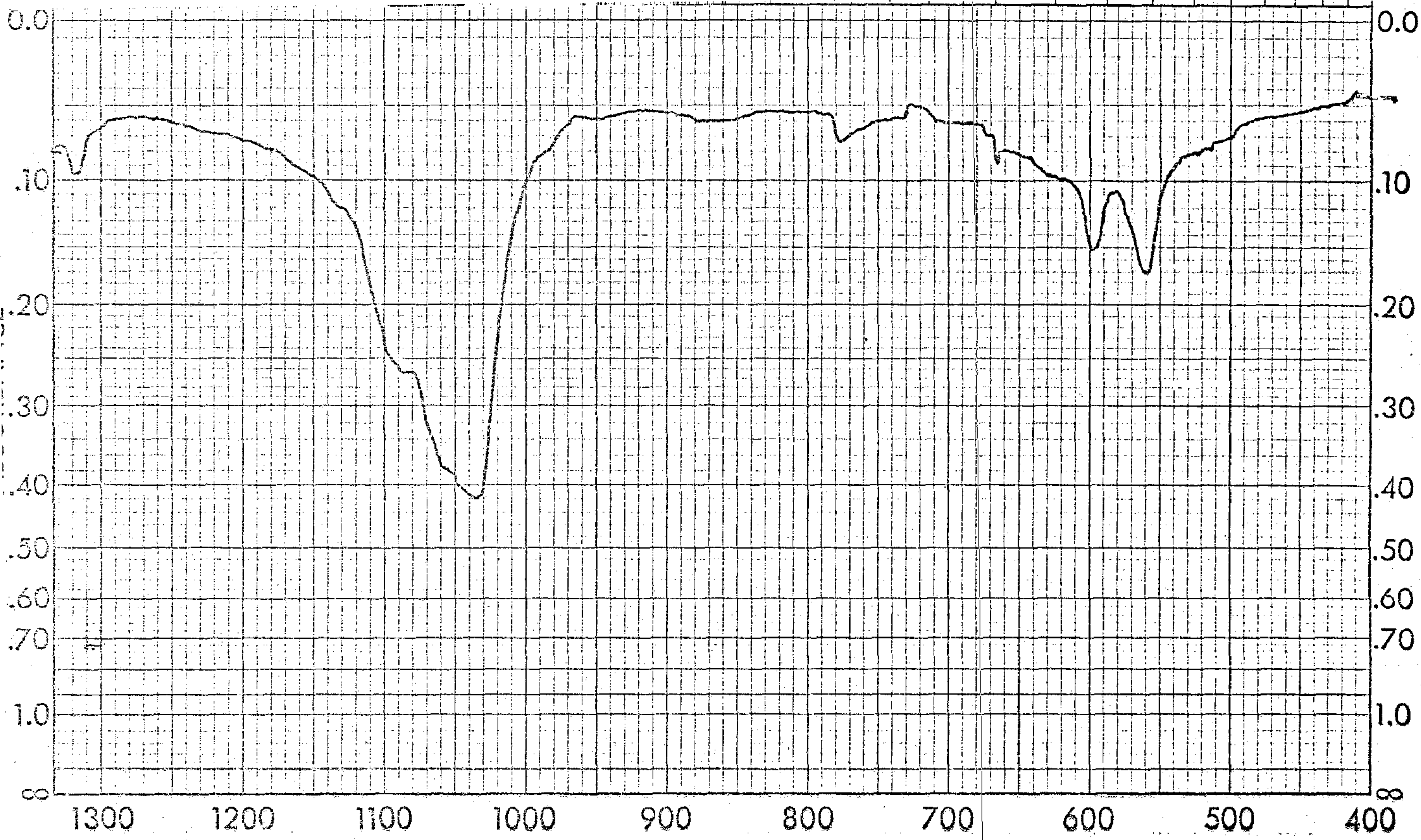


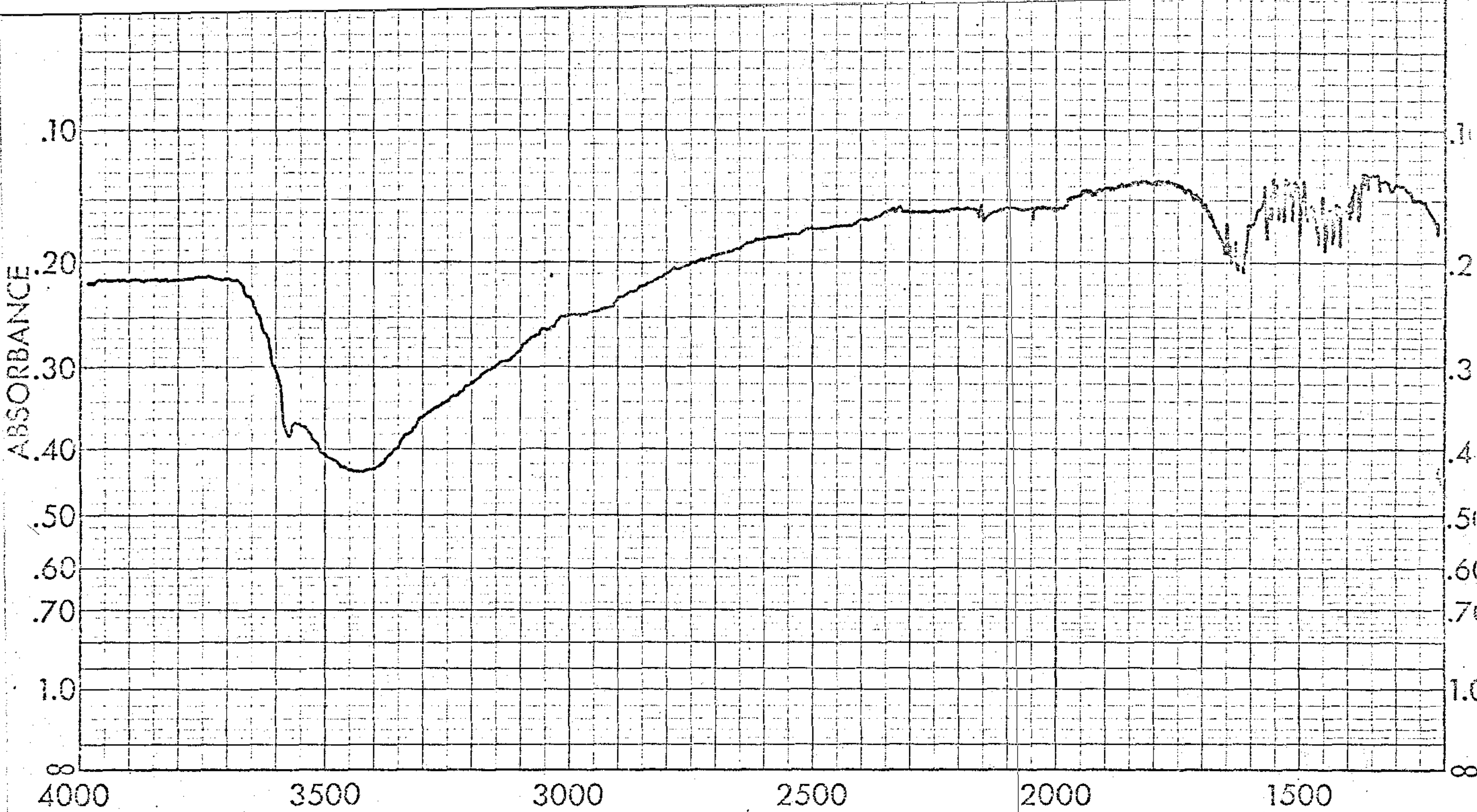
Spectrum No. 6: Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



Spectrum No. 6: Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



Spectrum No. 7: Tricalcium Phosphate, $Ca_3(PO_4)_2$ By Transmission I.R.



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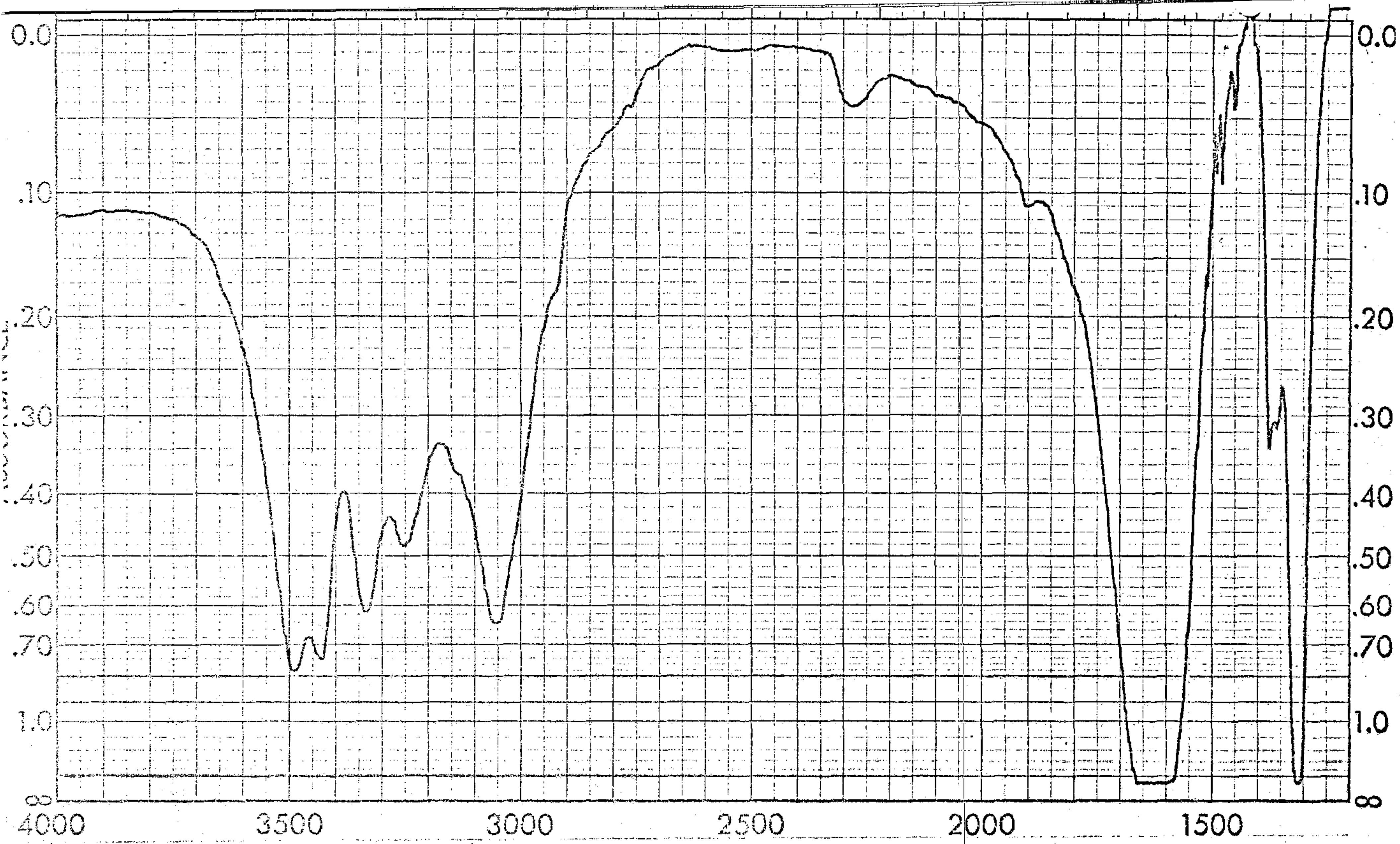
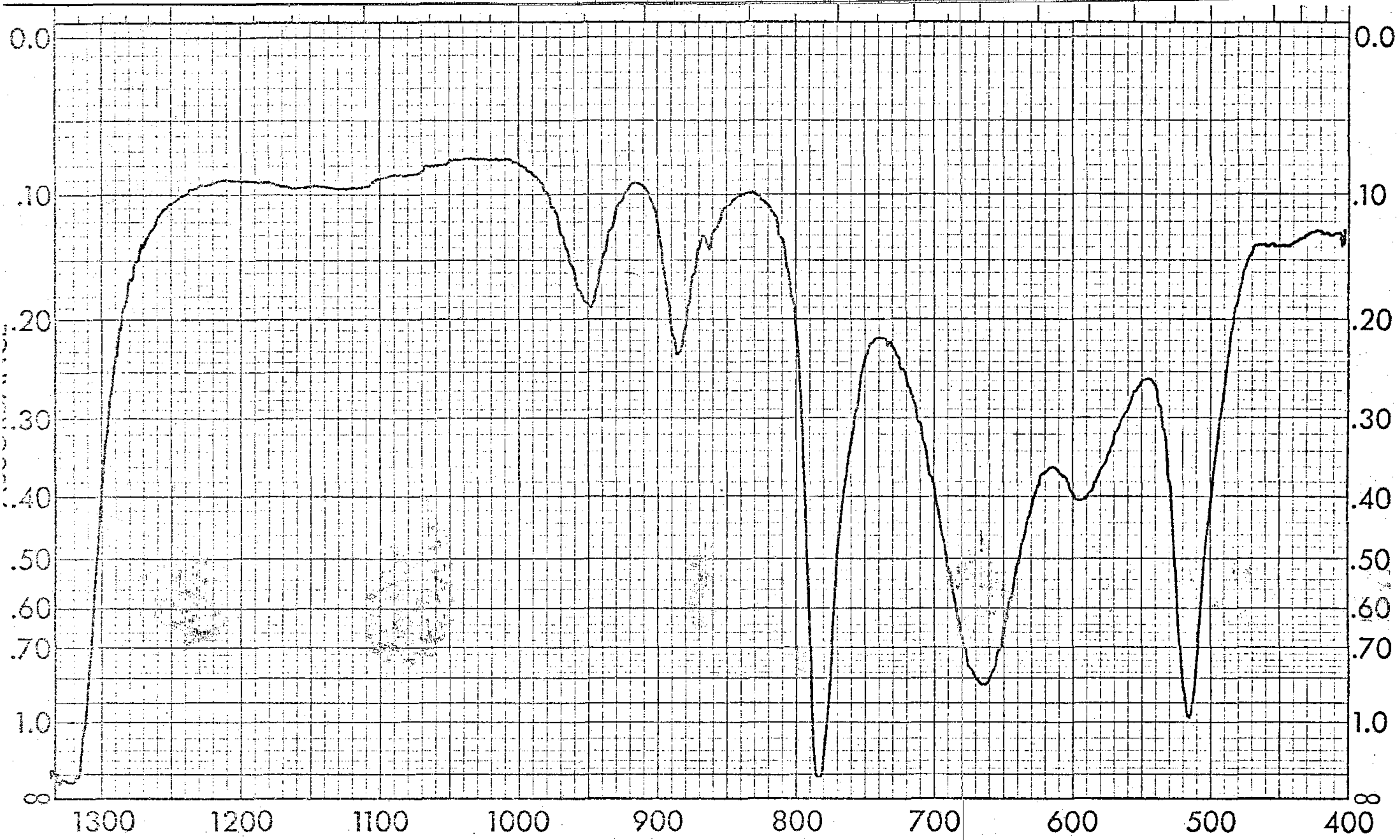


Spectrum No. 8: Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$ By Transmission I.R.



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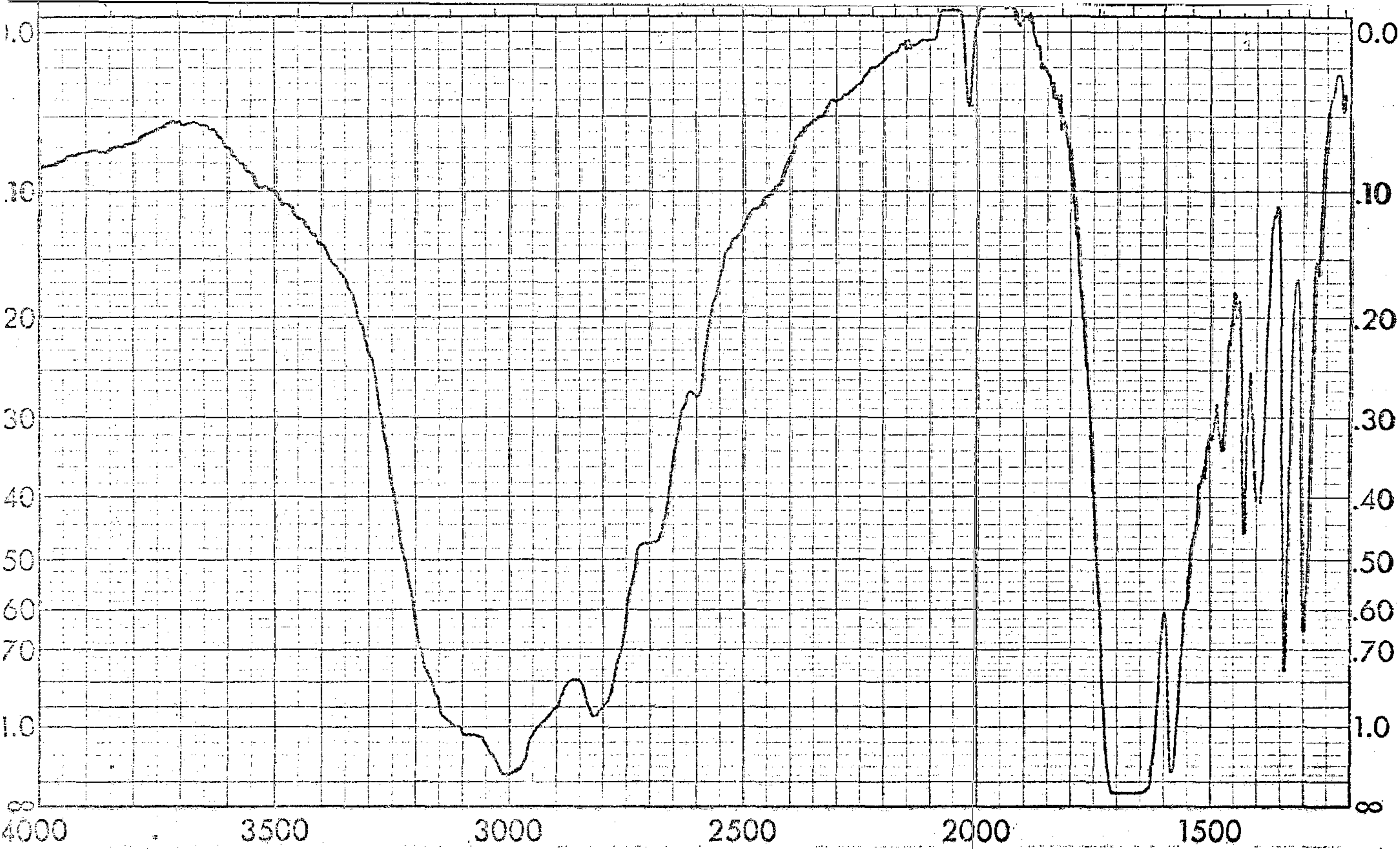
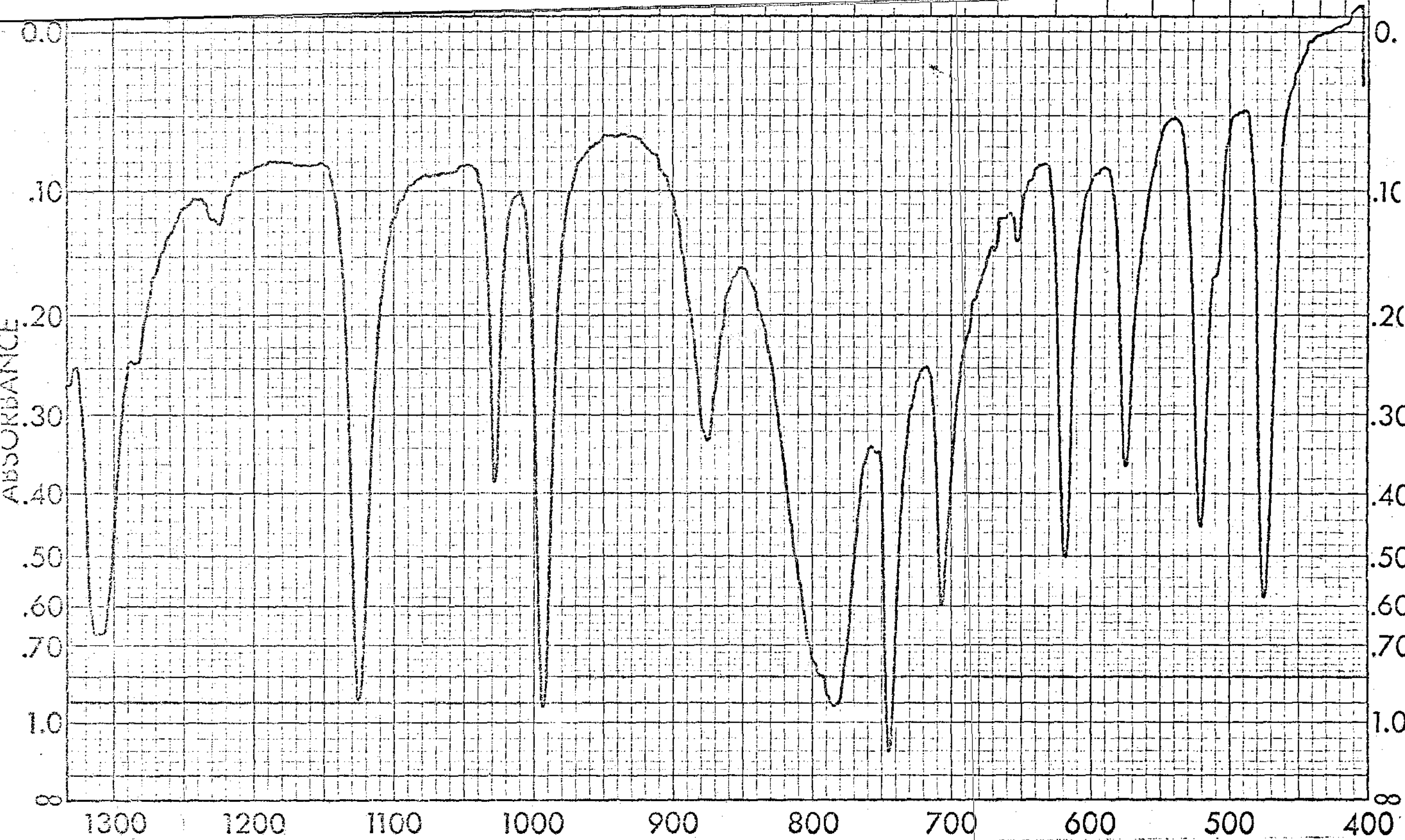
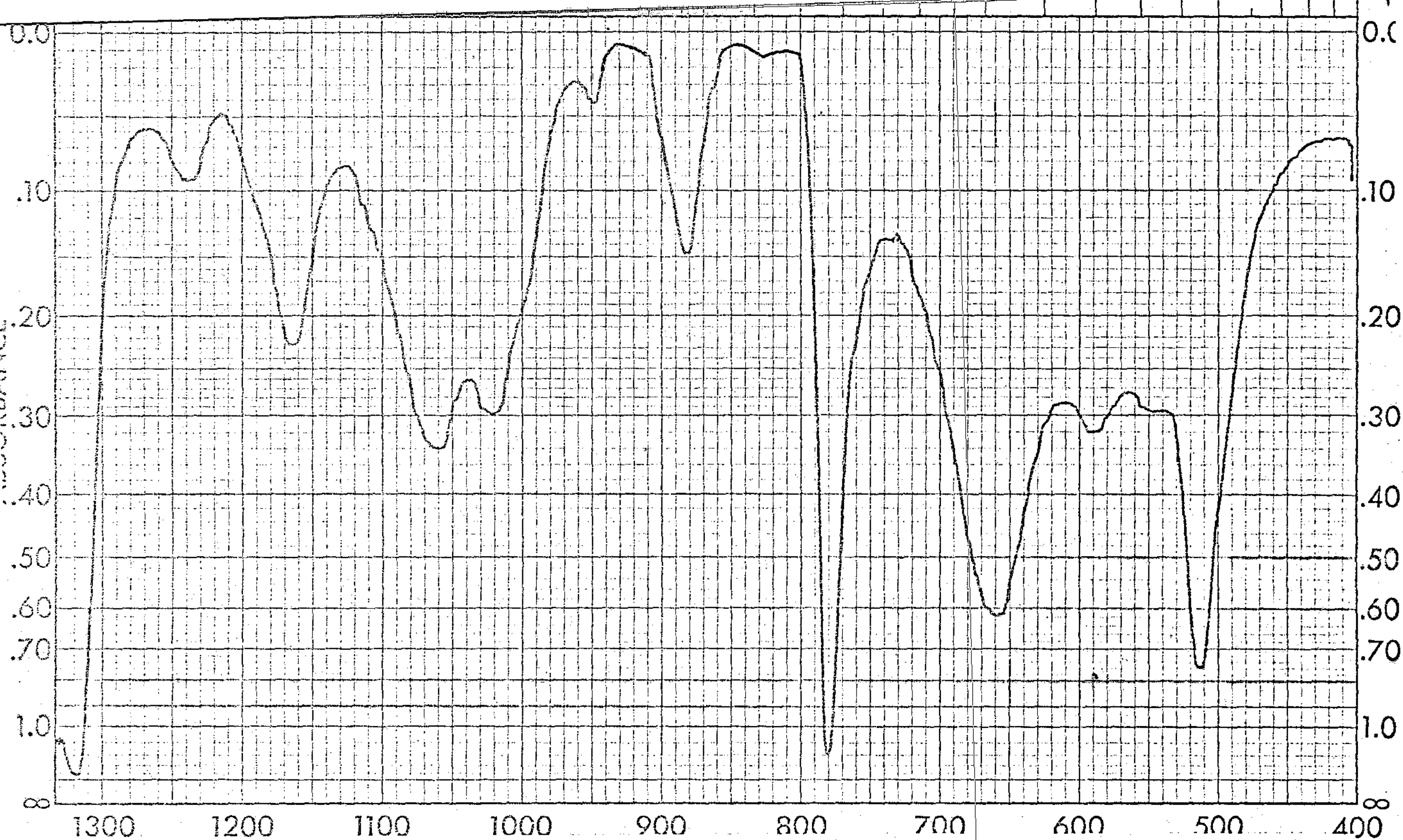


Spectrum No. 9: Uric Acid, $C_5H_4N_4O_3$ By Transmission I.R.

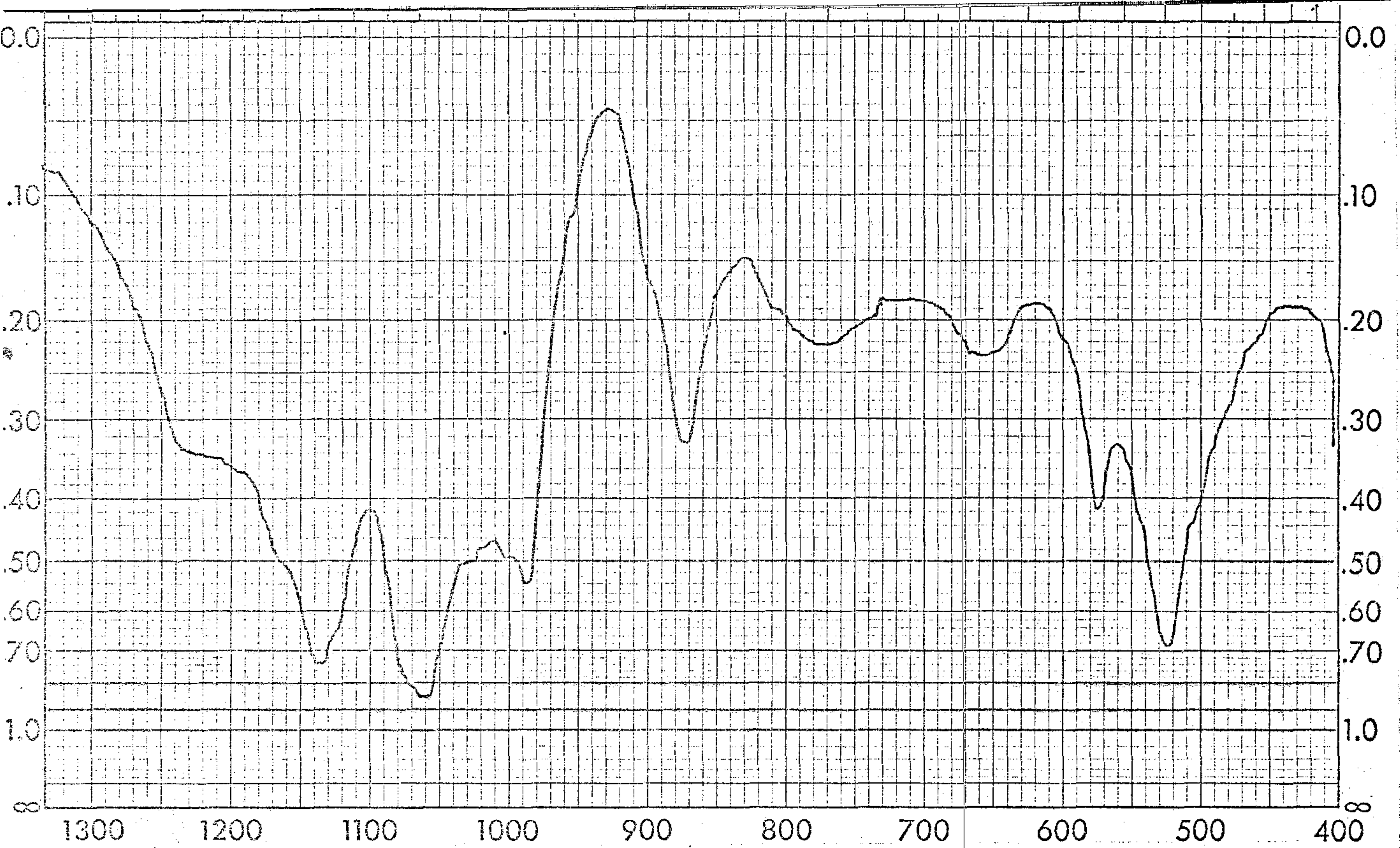


Spectrum No. 9: Uric Acid, $C_5H_4N_4O_3$ By Transmission. I.R.

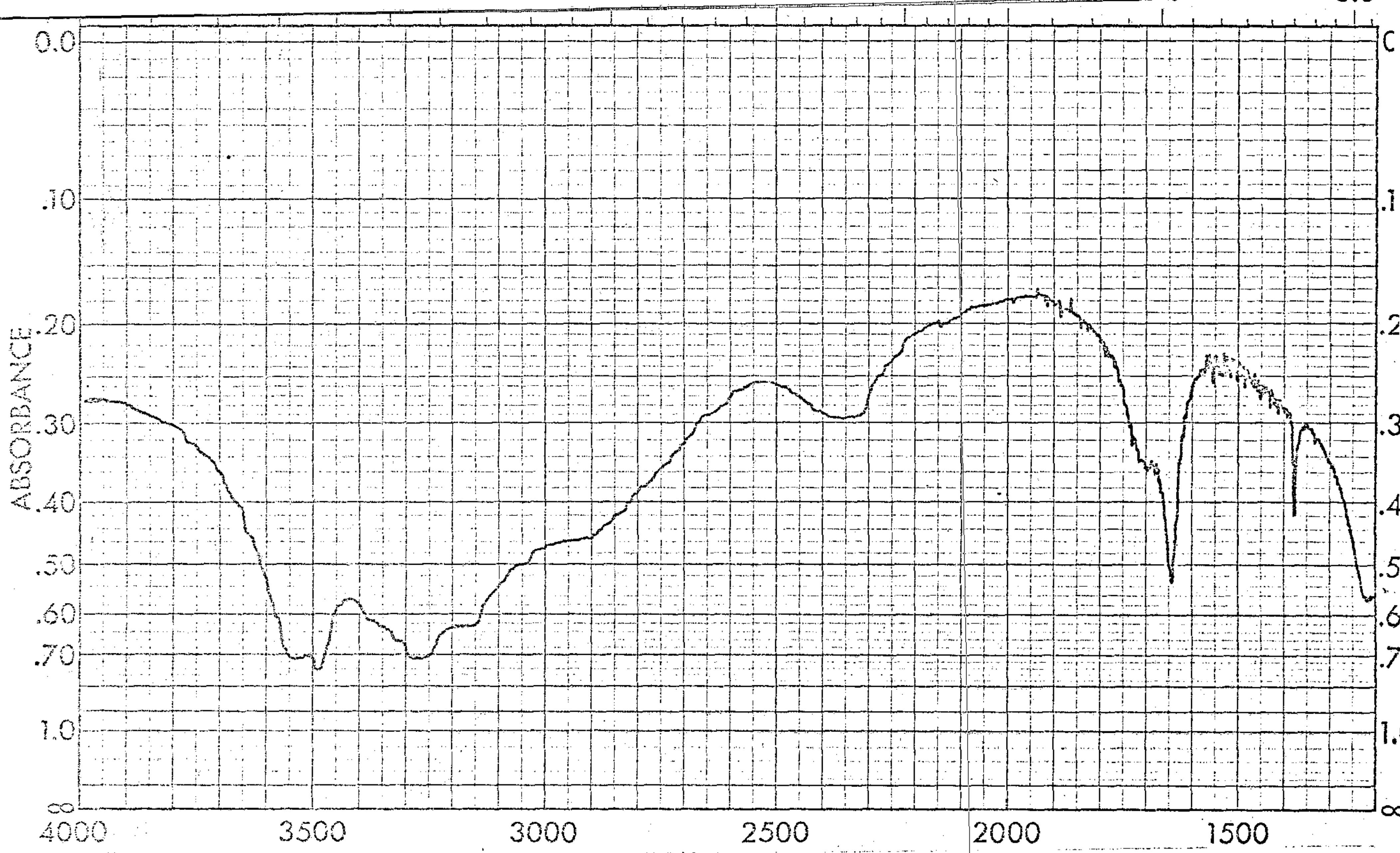


Spectrum No. 10: 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, and 50% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.

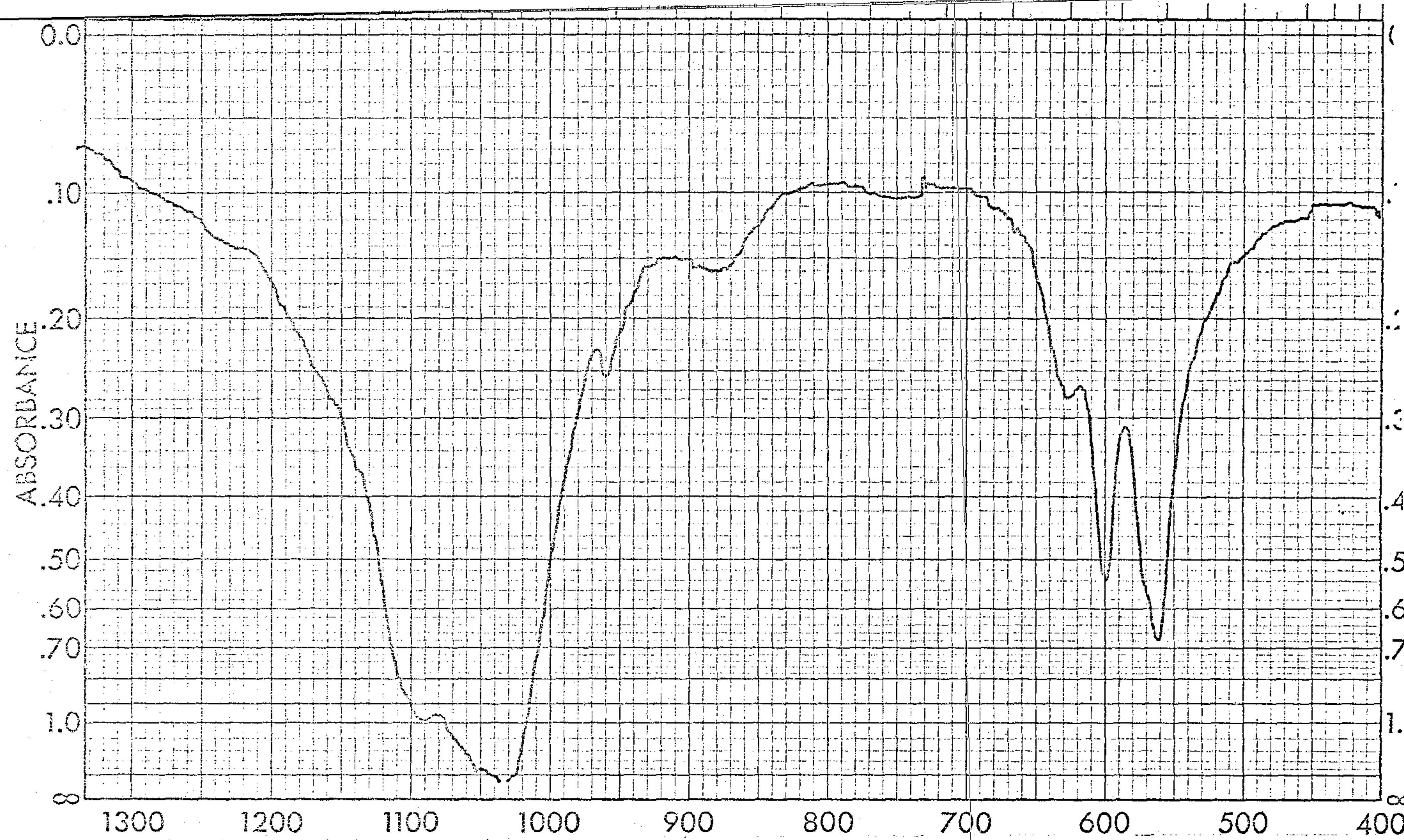
Spectrum No. 10: 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, and 50% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



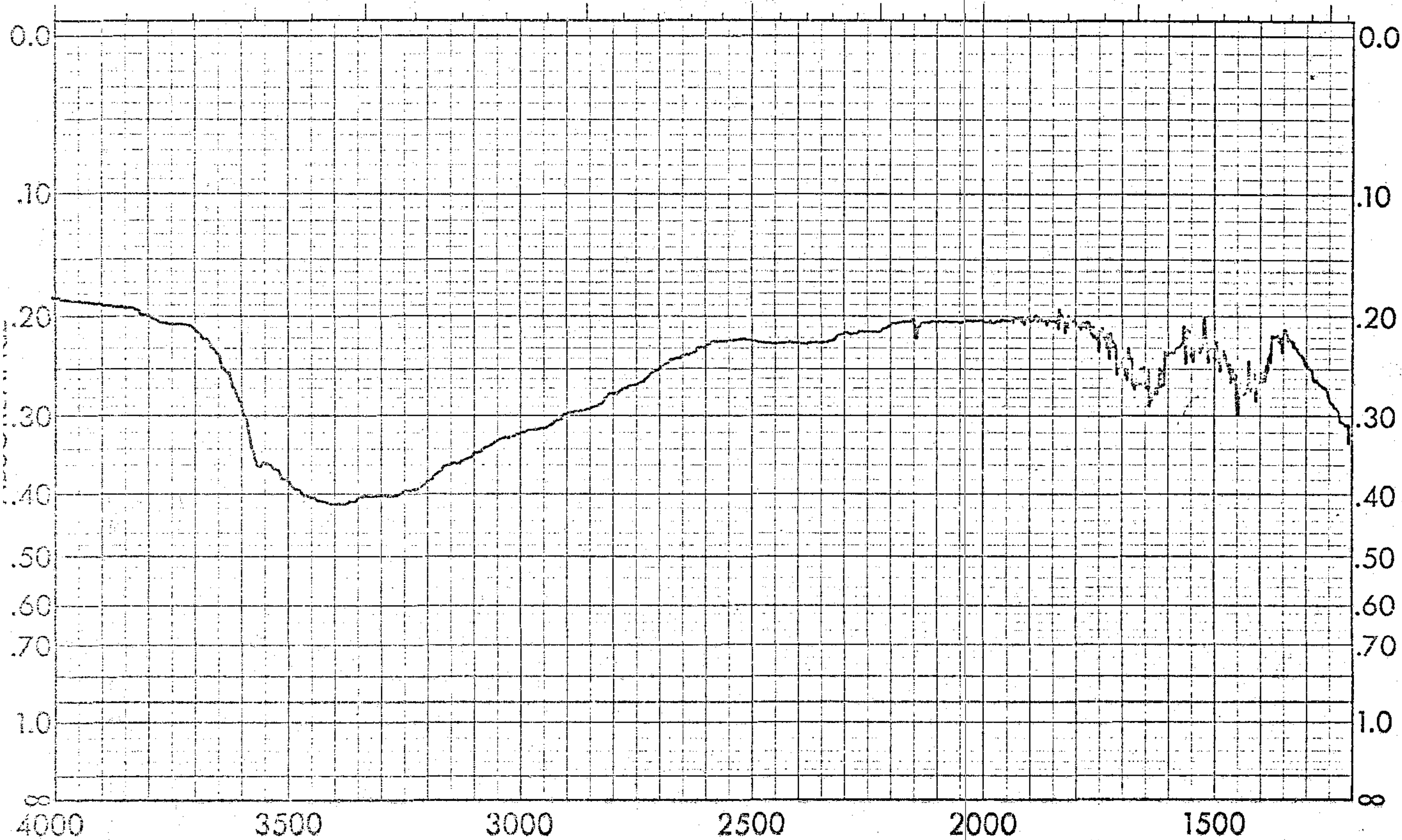
Spectrum No. 11: 50% Magnesium Phosphate, $MgHPO_4$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.



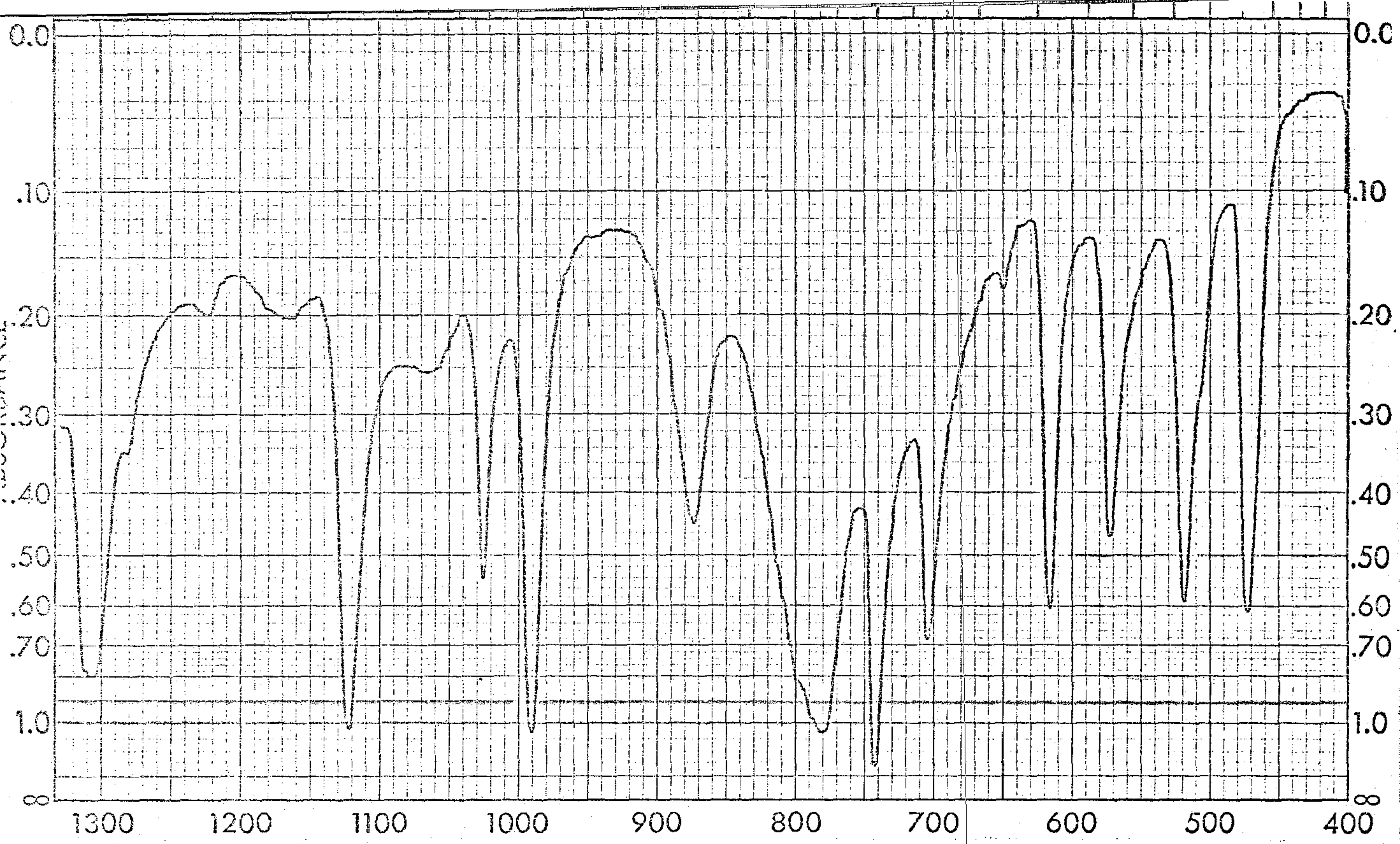
Spectrum No. 11: 50% Magnesium Phosphate, $MgHPO_4$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.



Spectrum No. 12: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ By Transmission I.R.



Spectrum No. 12: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ By Transmission I.R.



Spectrum No. 13: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ By Transmission I.R.

Spectrum No. 13: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ By Transmission I.R.

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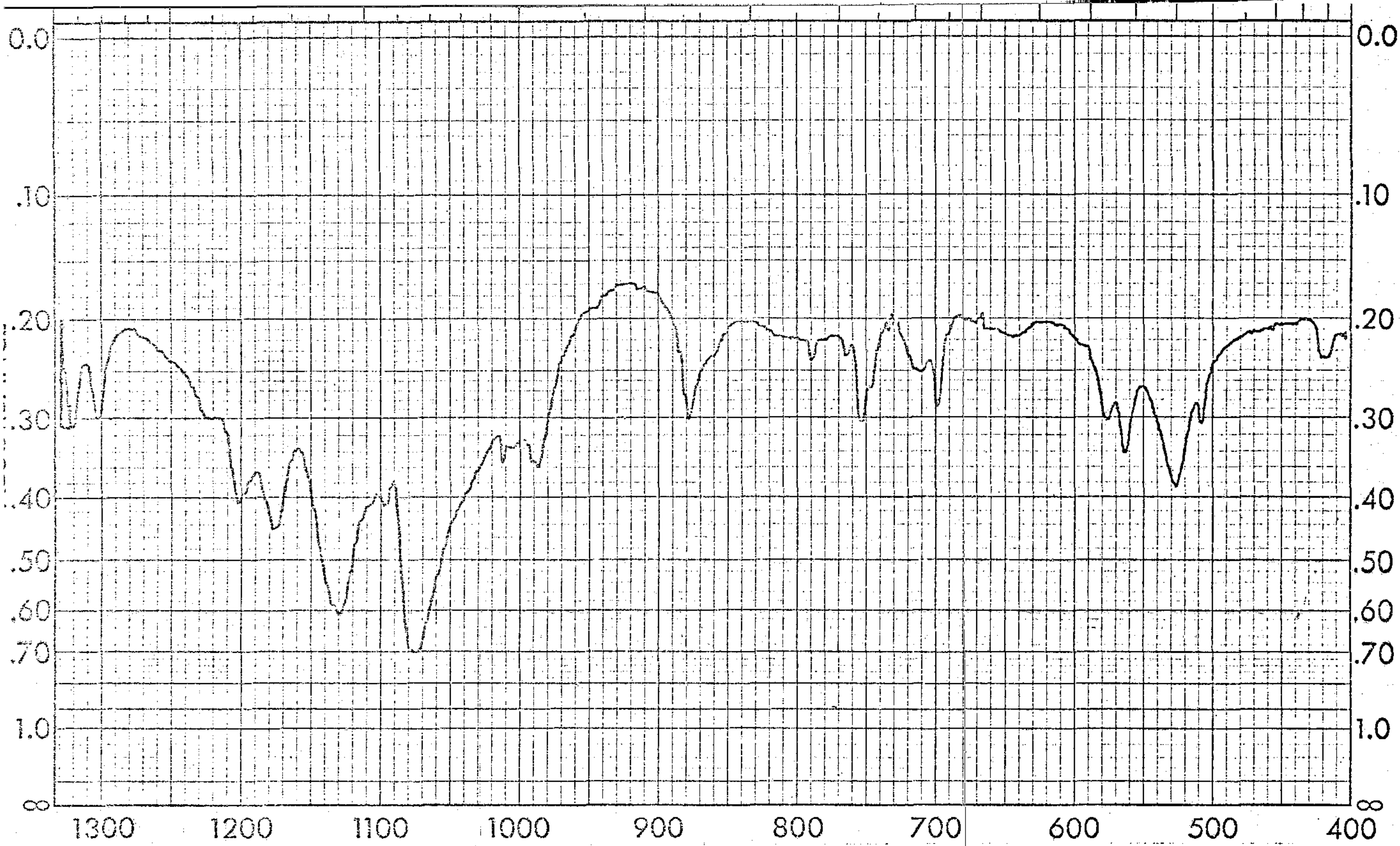
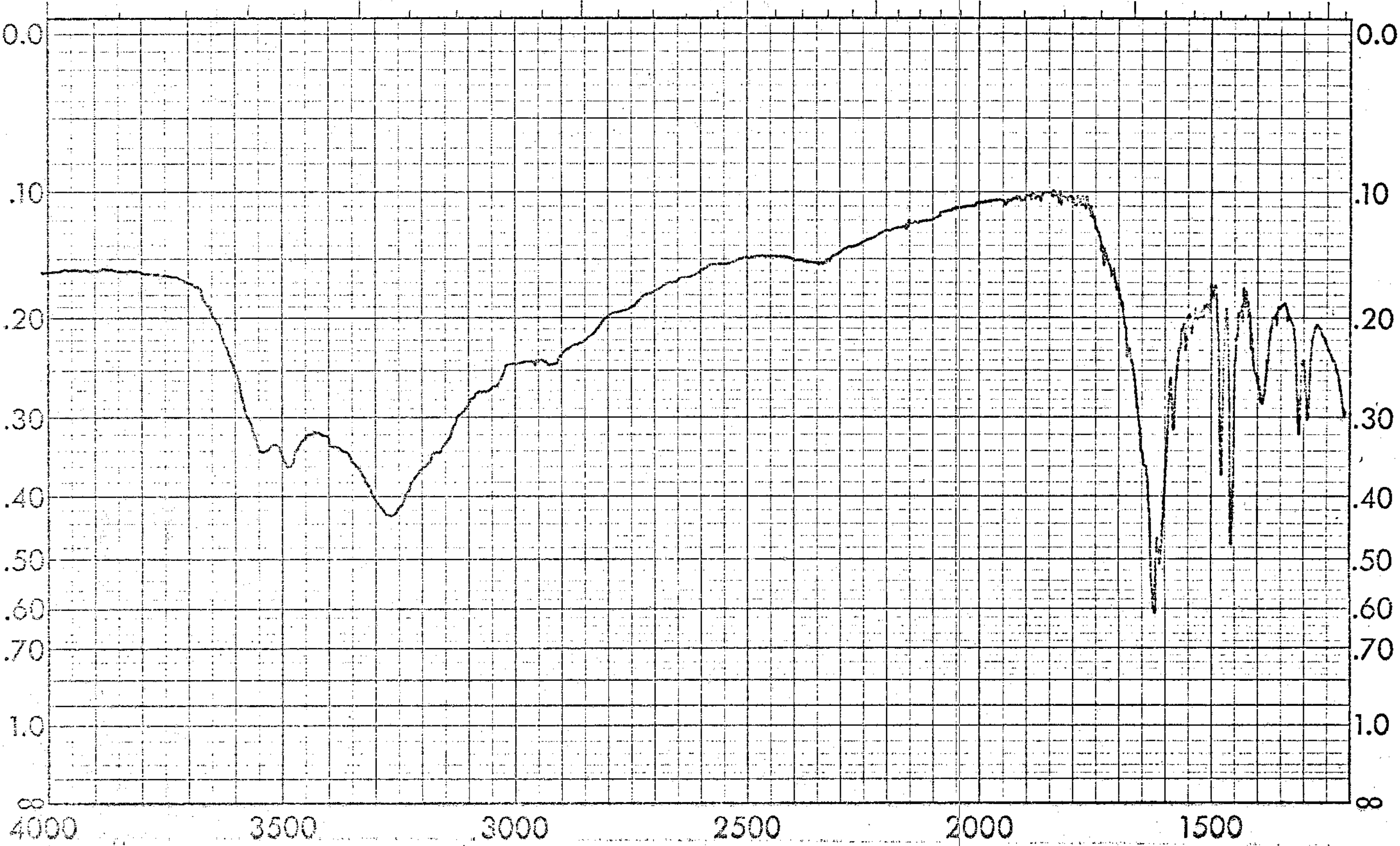
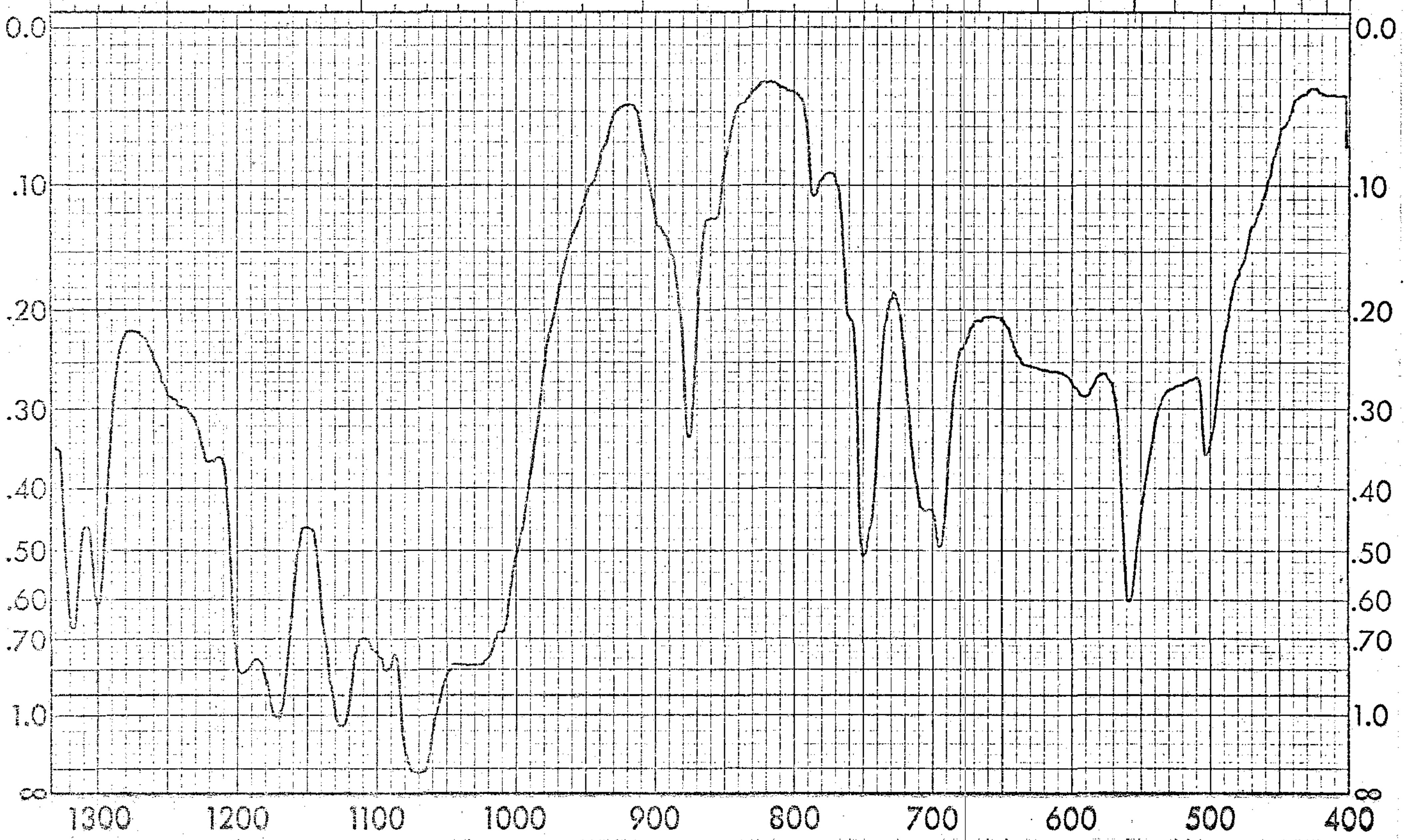


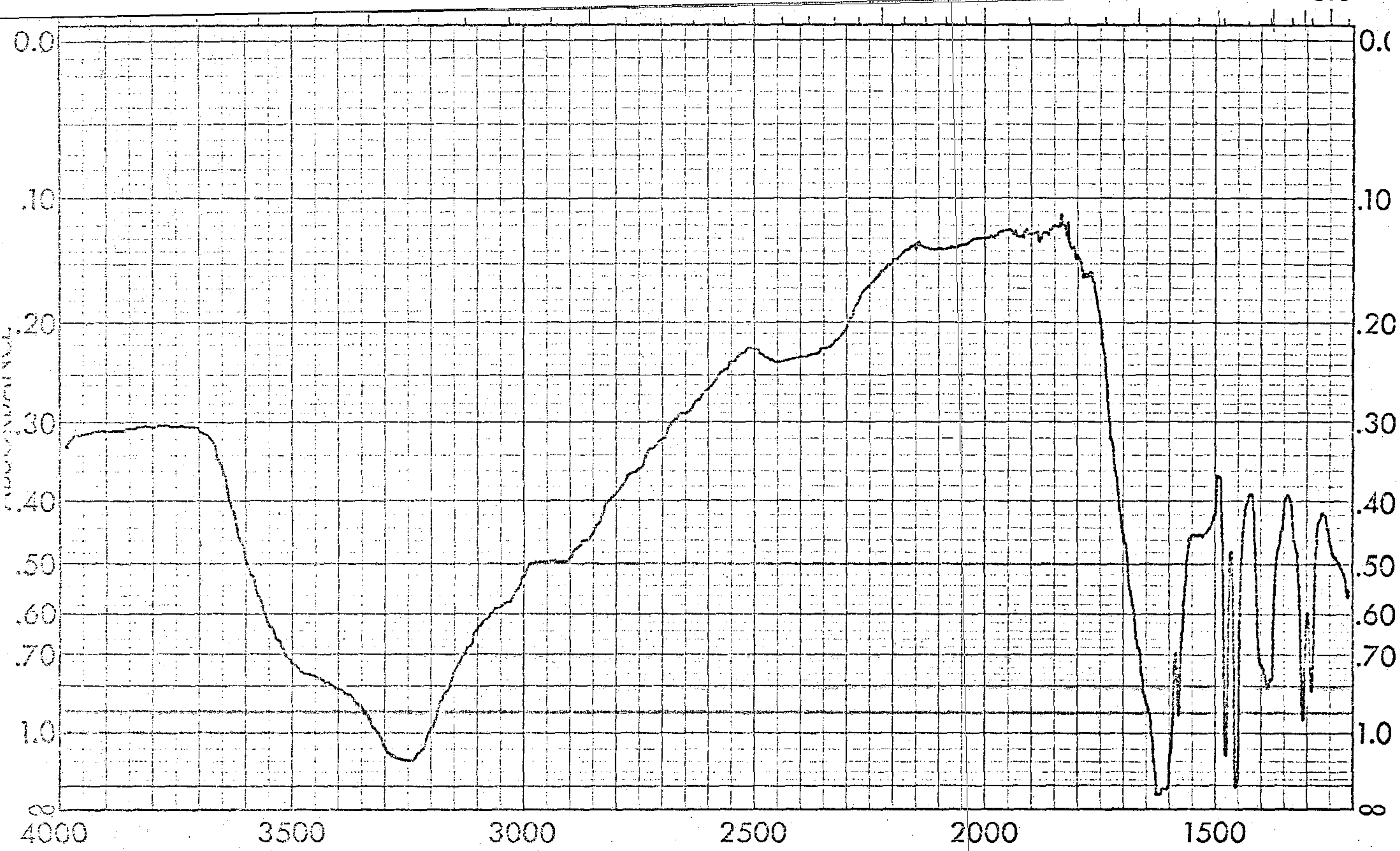
Spectrum No. 14: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.



Spectrum No. 14: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.

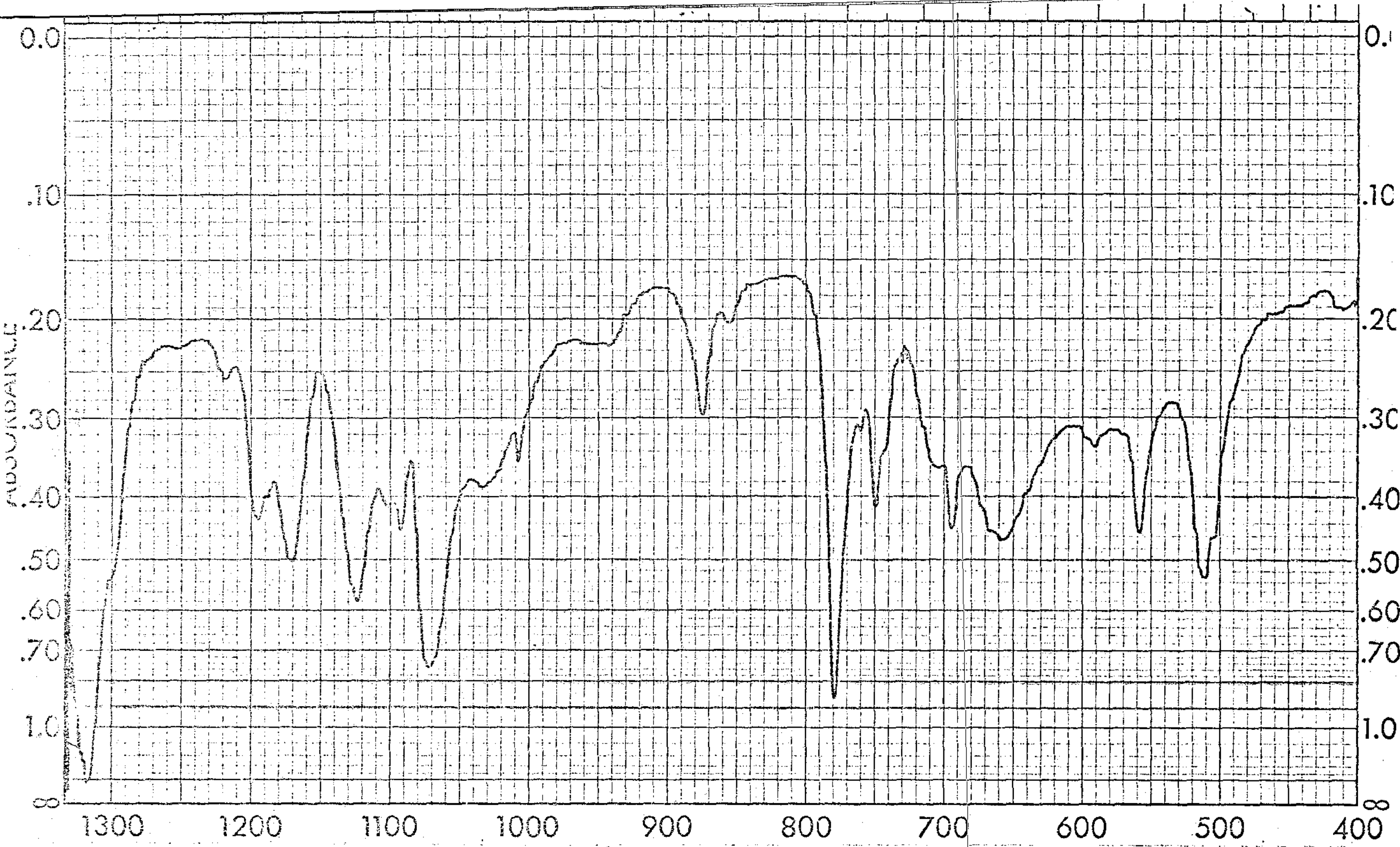


Spectrum No. 15: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.

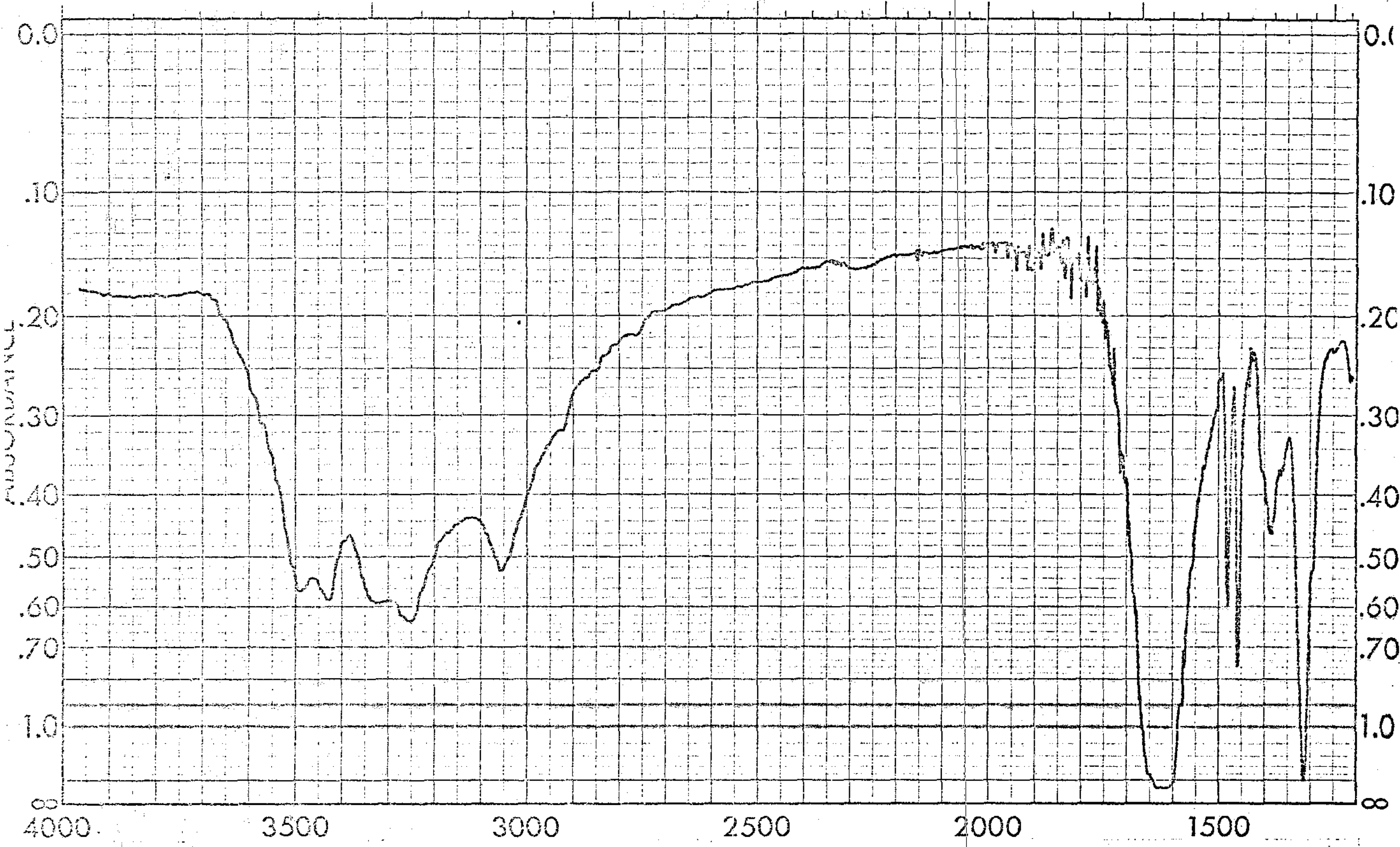


Spectrum No. 15: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Magnesium Phosphate,

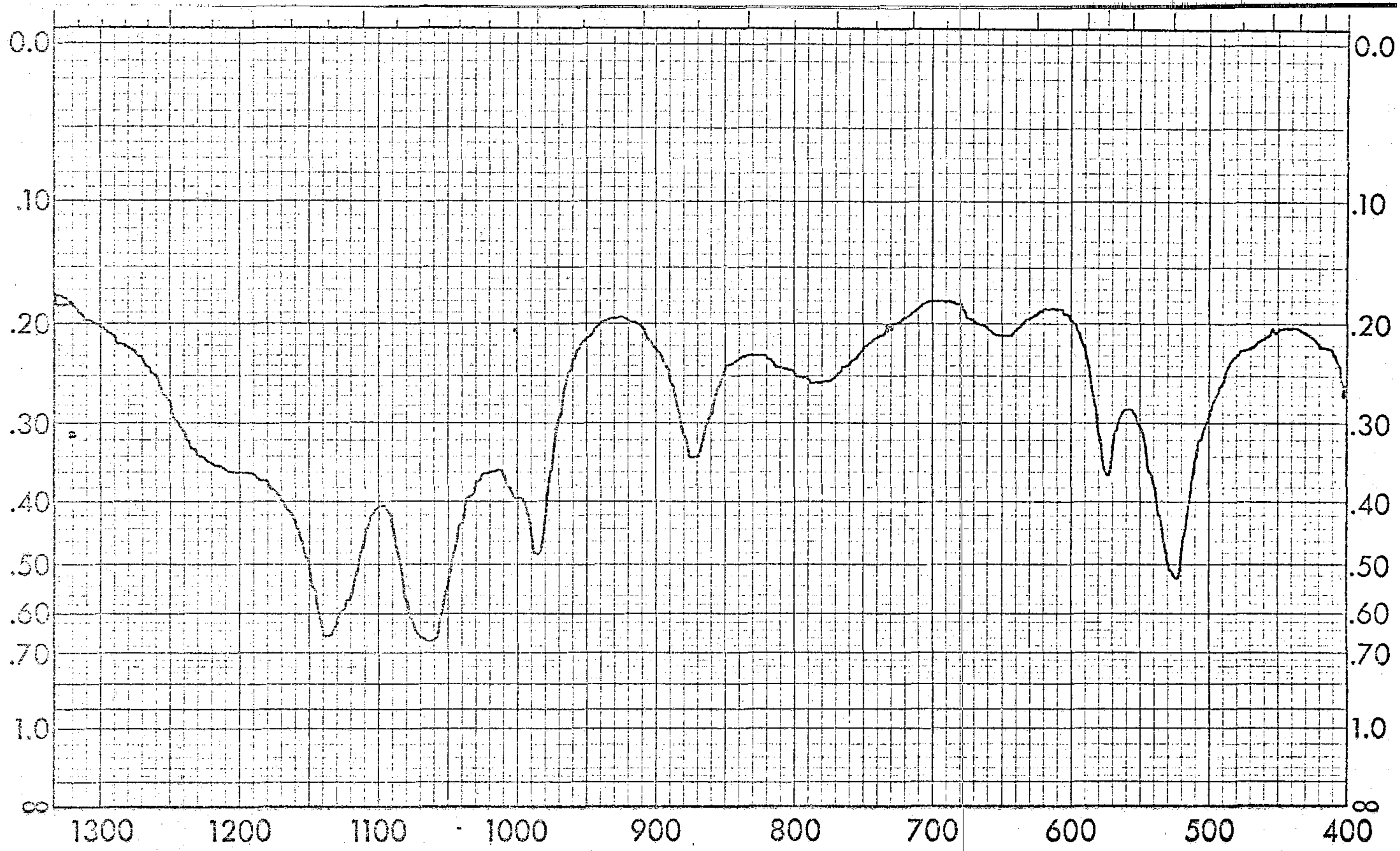
$MgHPO_4$ By Transmission. I.R.



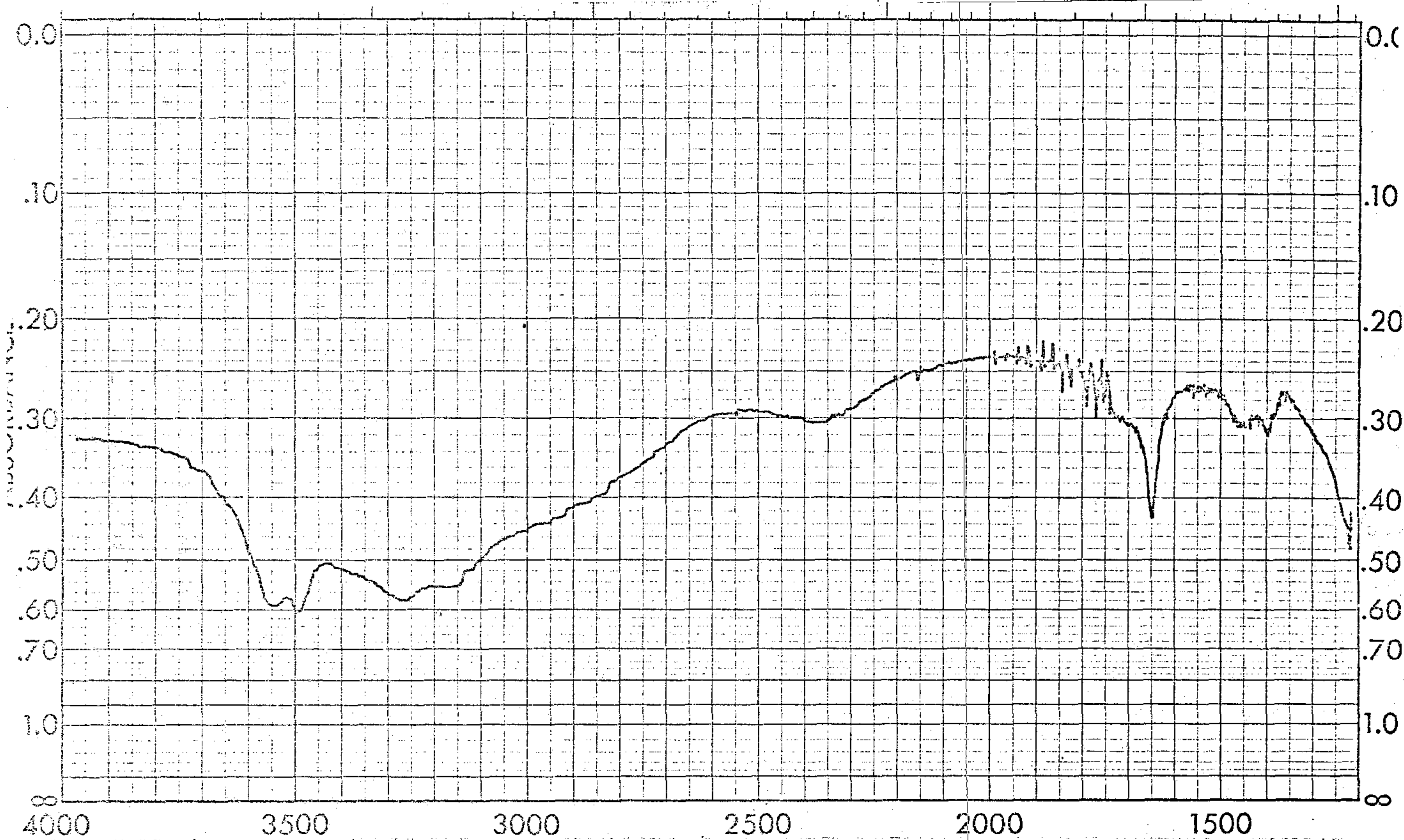
Spectrum No. 16: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ By Transmission I.R.



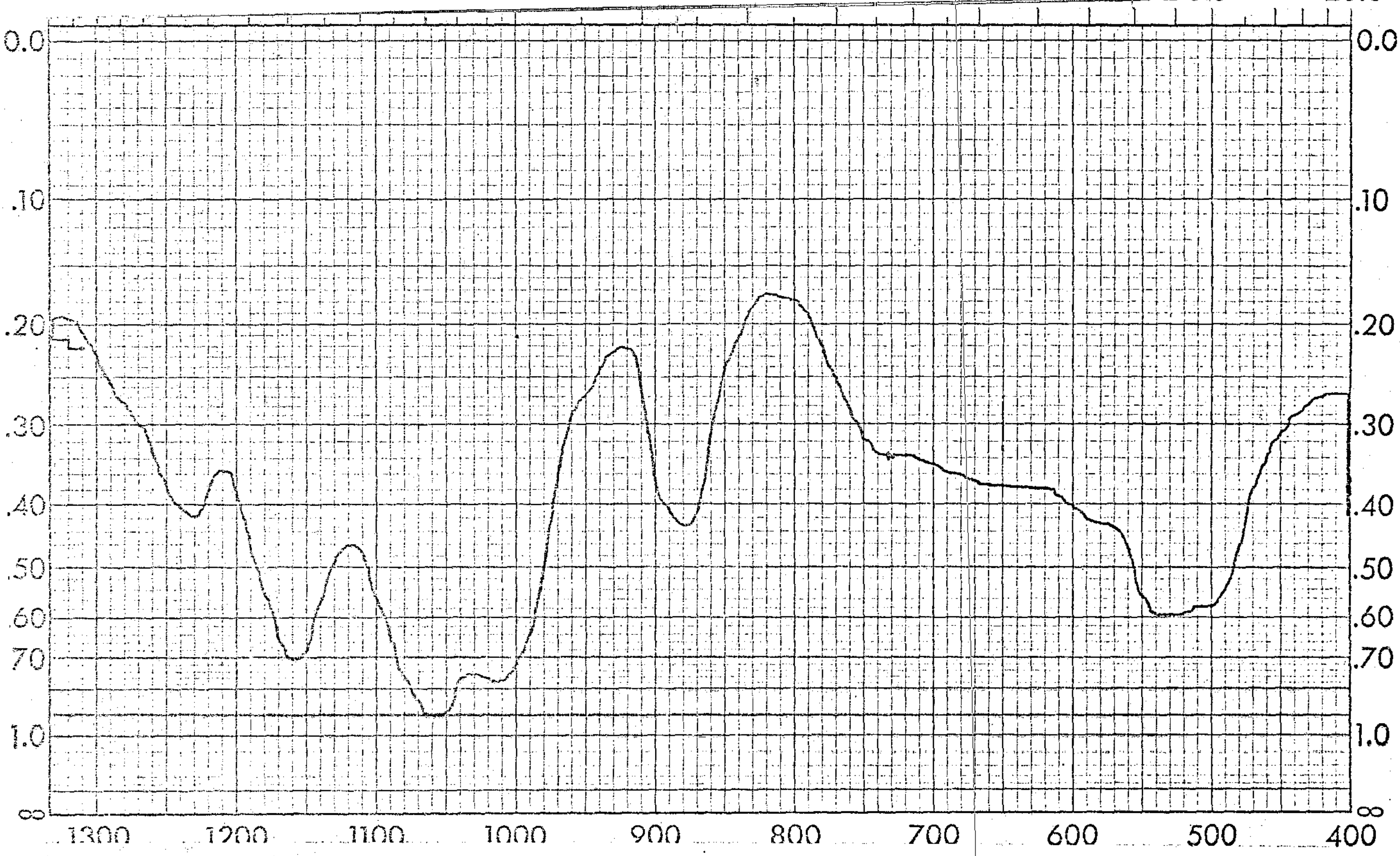
Spectrum No. 16: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$ By Transmission. I.R.



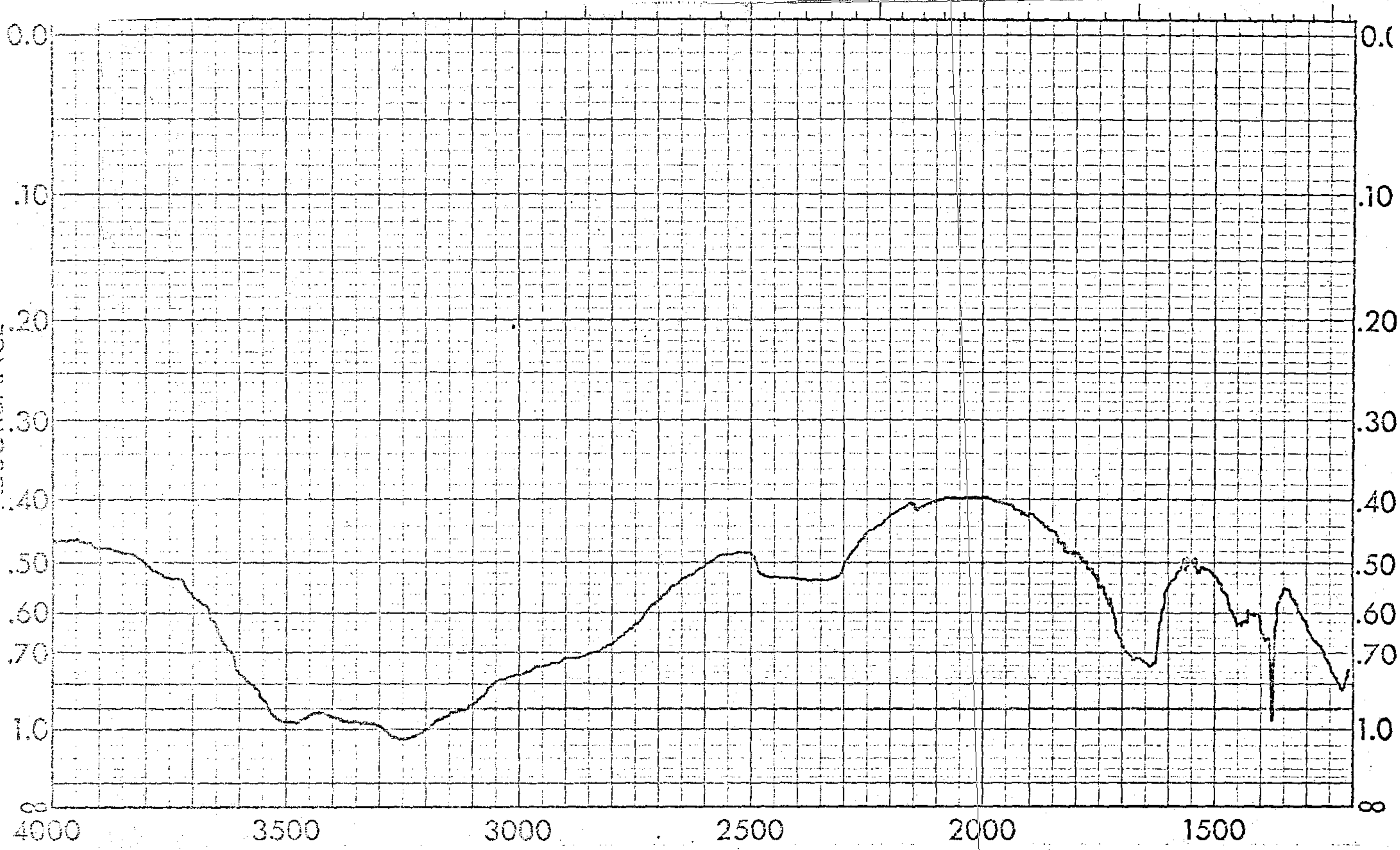
Spectrum No. 17: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.



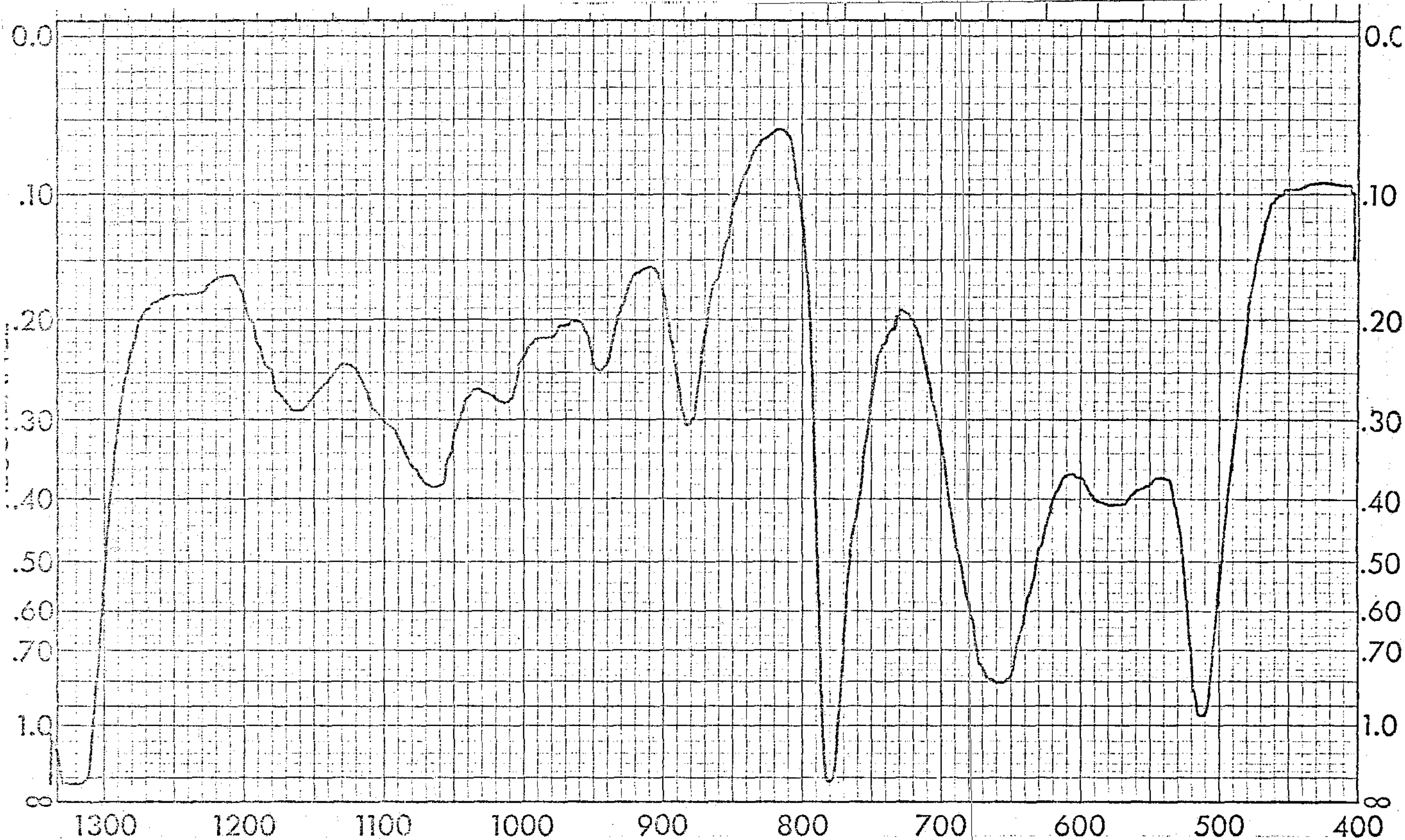
Spectrum No. 17 : 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.



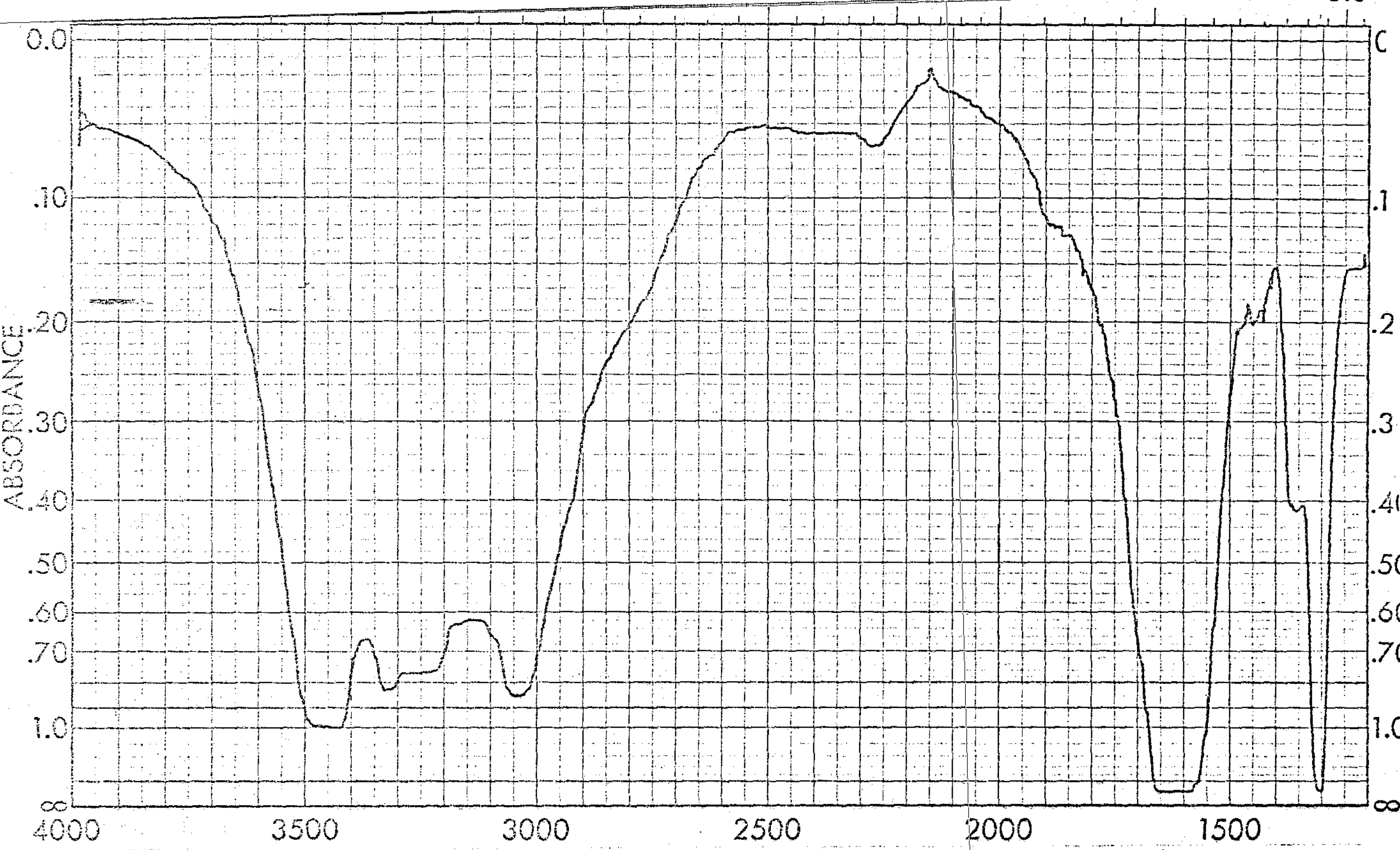
Spectrum No. 18: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 50% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



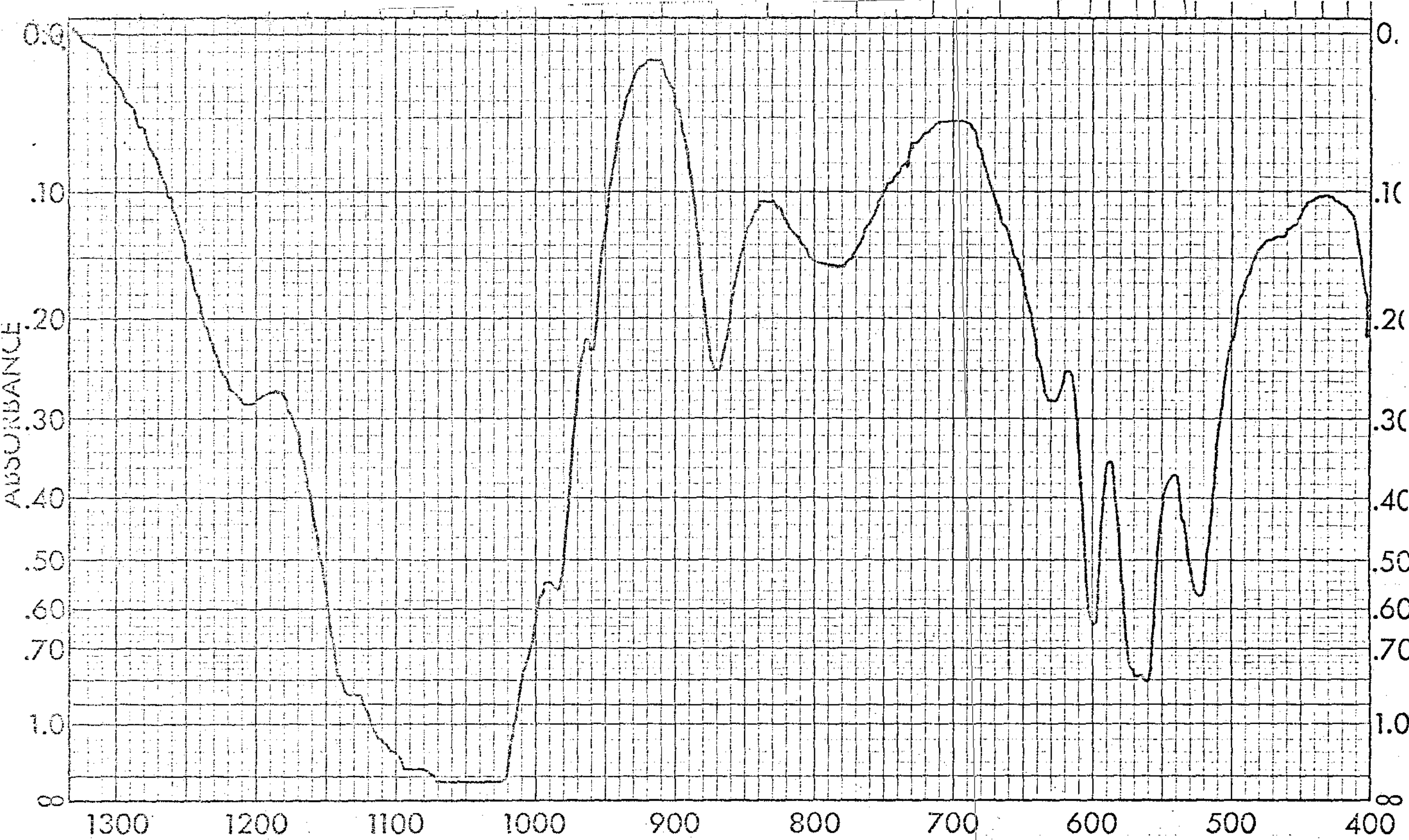
Spectrum No. 18: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 50% Magnesium Phosphate, $MgHPO_4$ By Transmission, I.R.



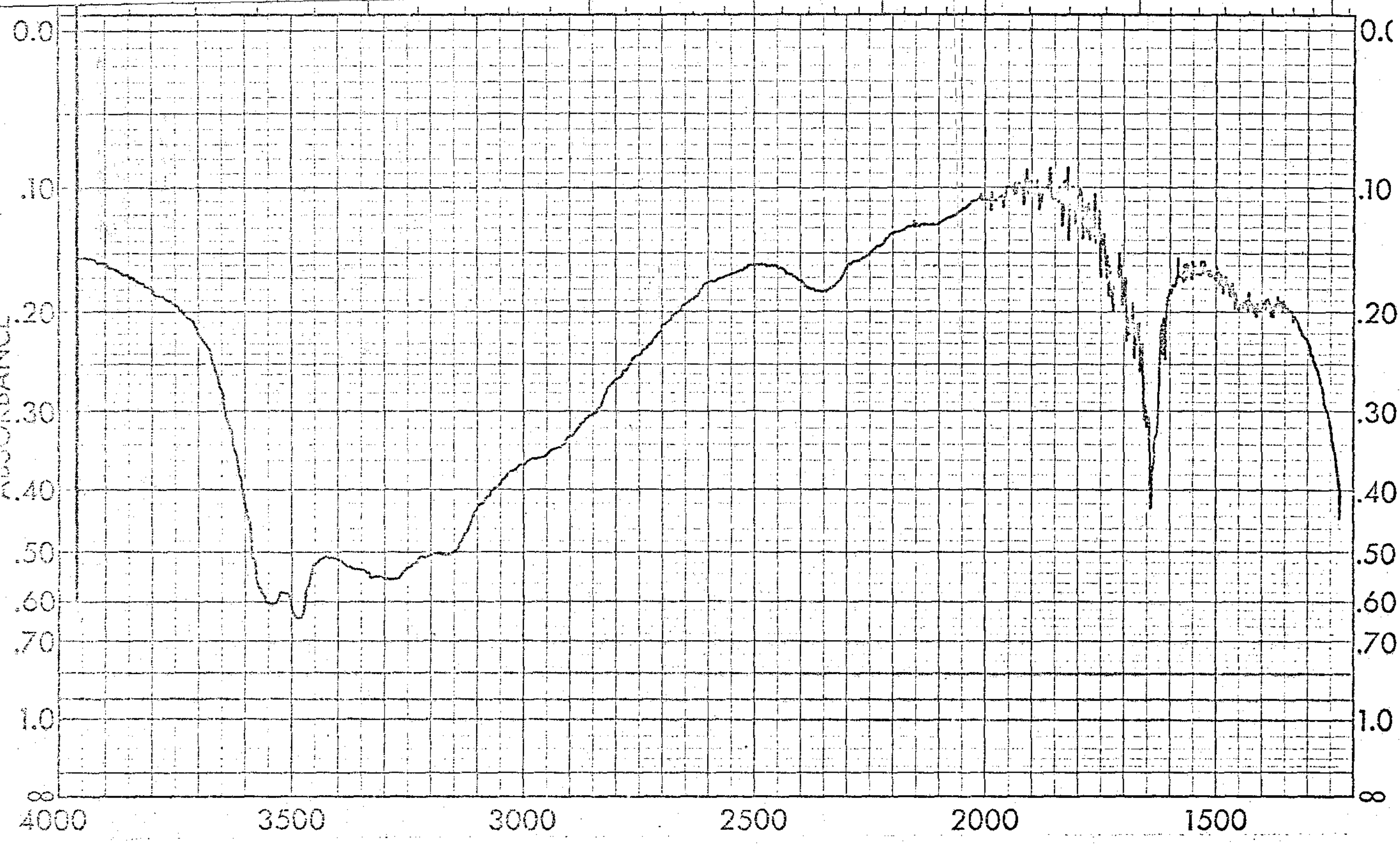
Spectrum No. 19: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$ By Transmission I.R.



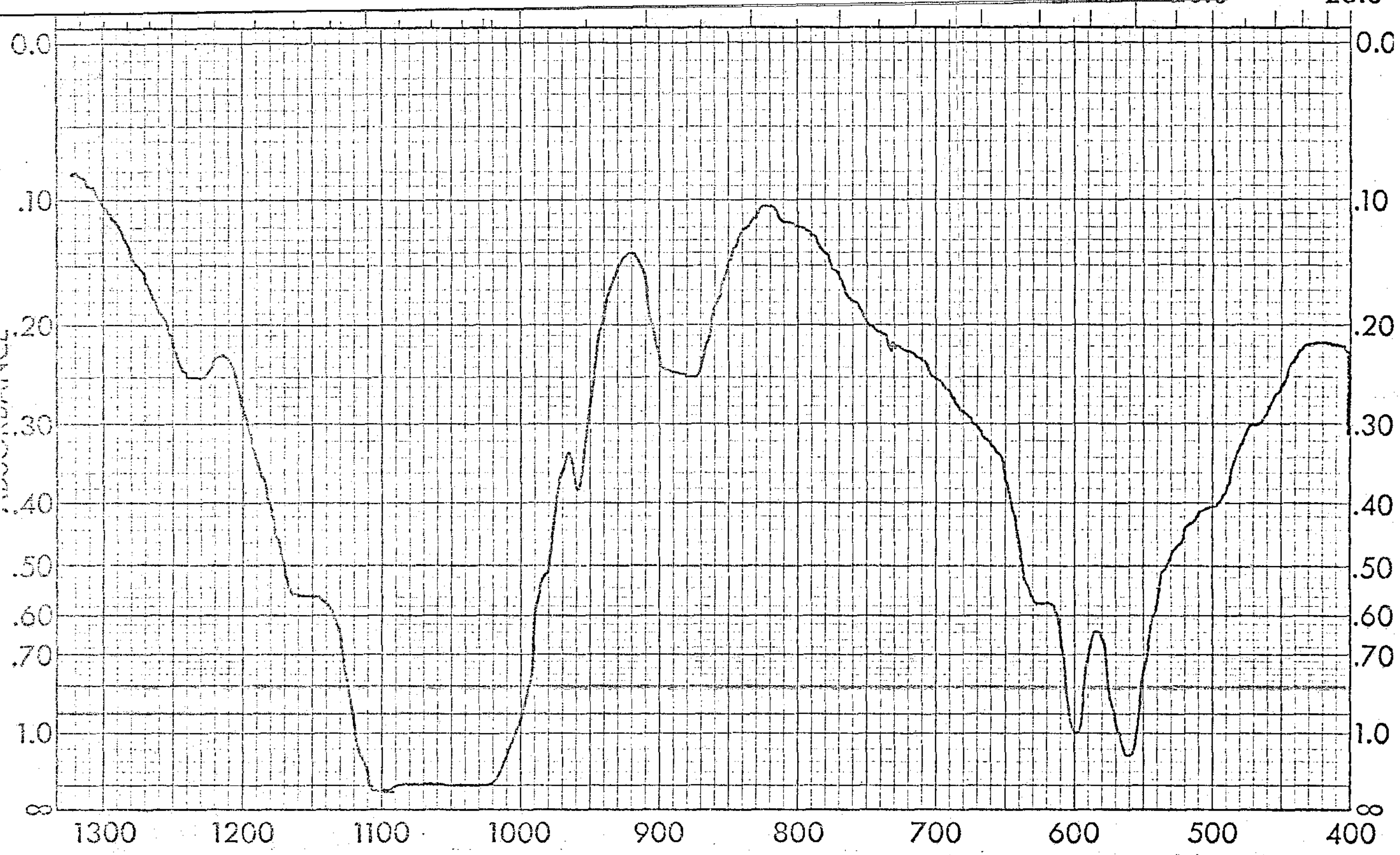
Spectrum No. 19: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ By Transmission I.R.



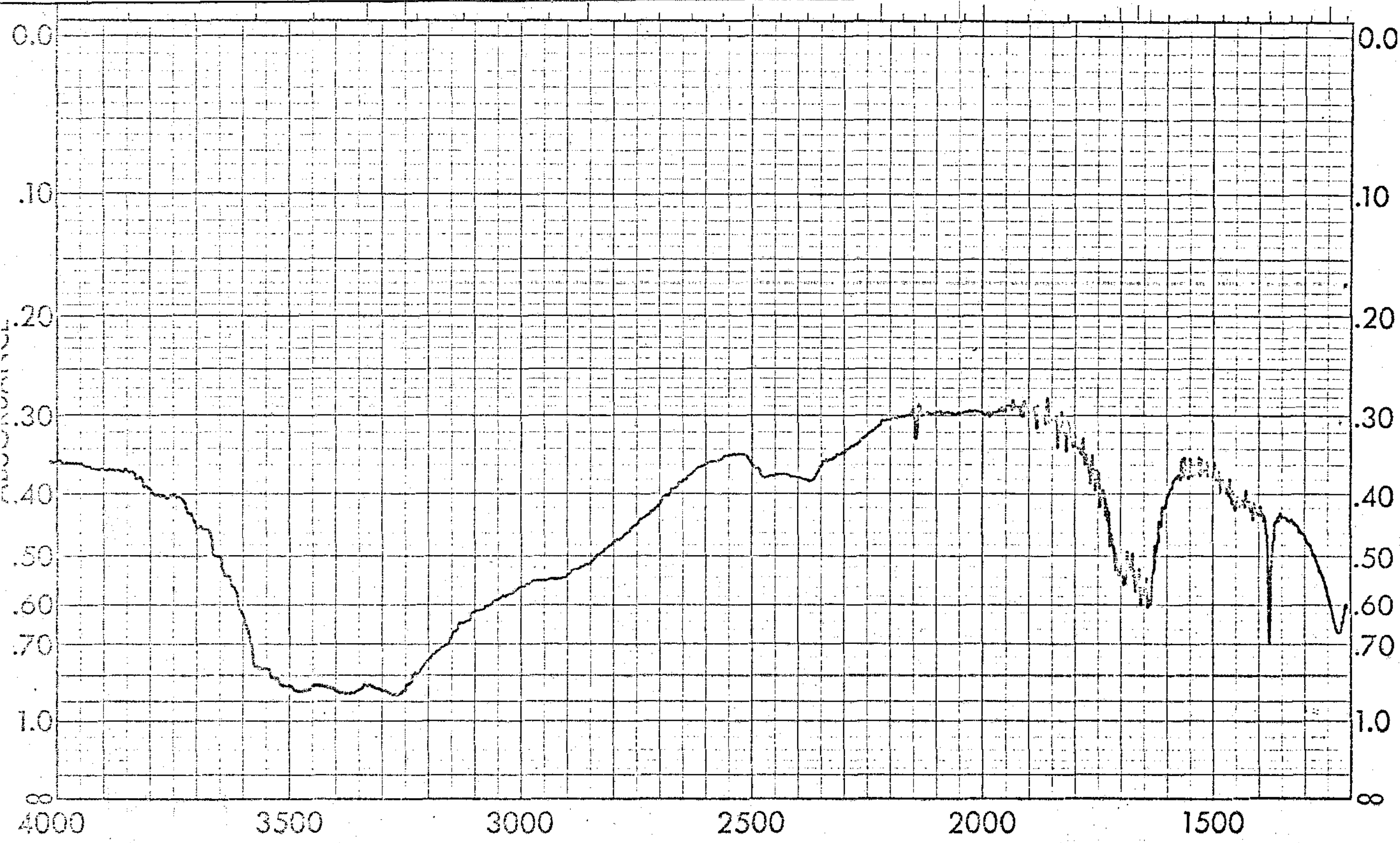
Spectrum No. 20: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.



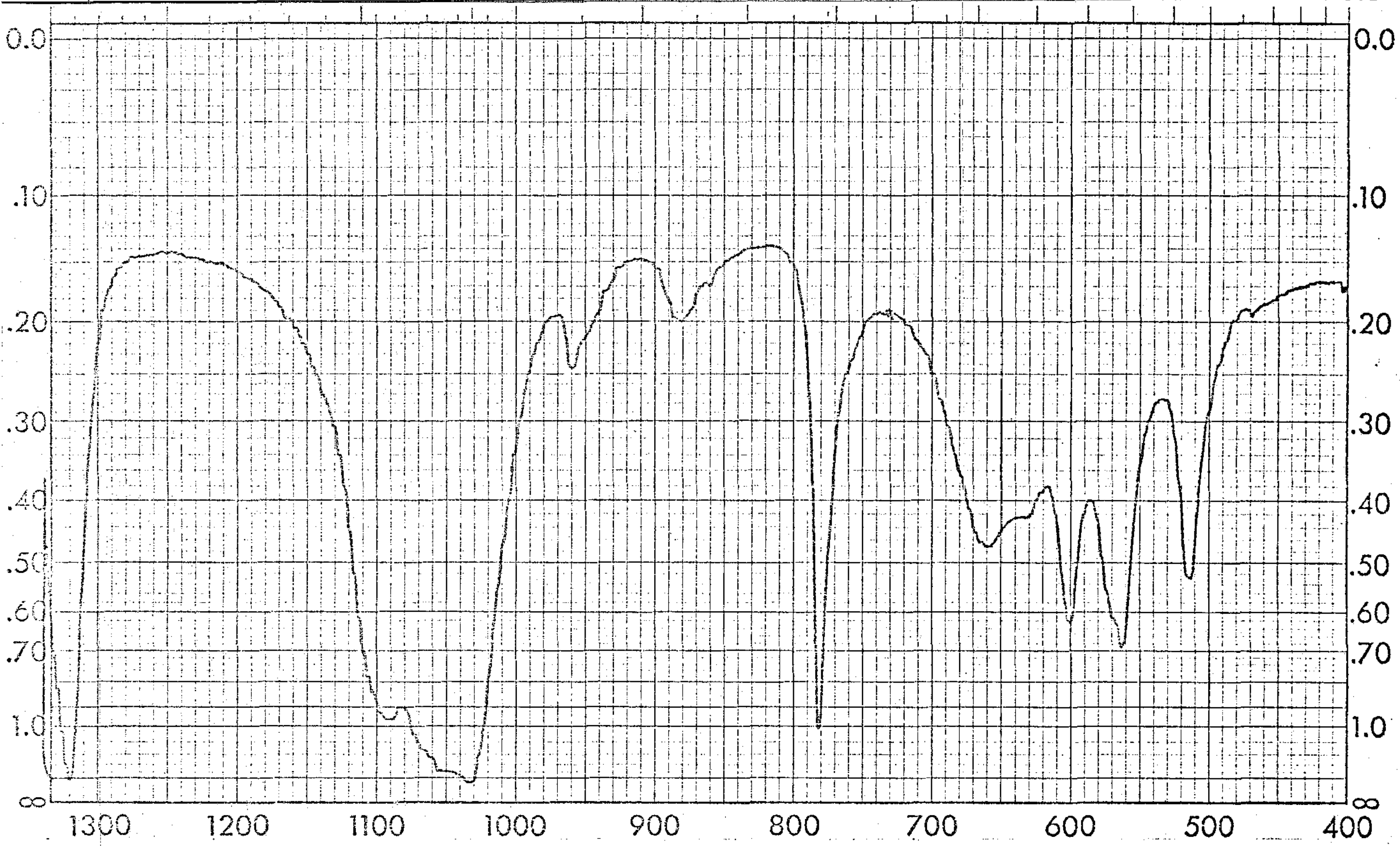
Spectrum No. 20: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.



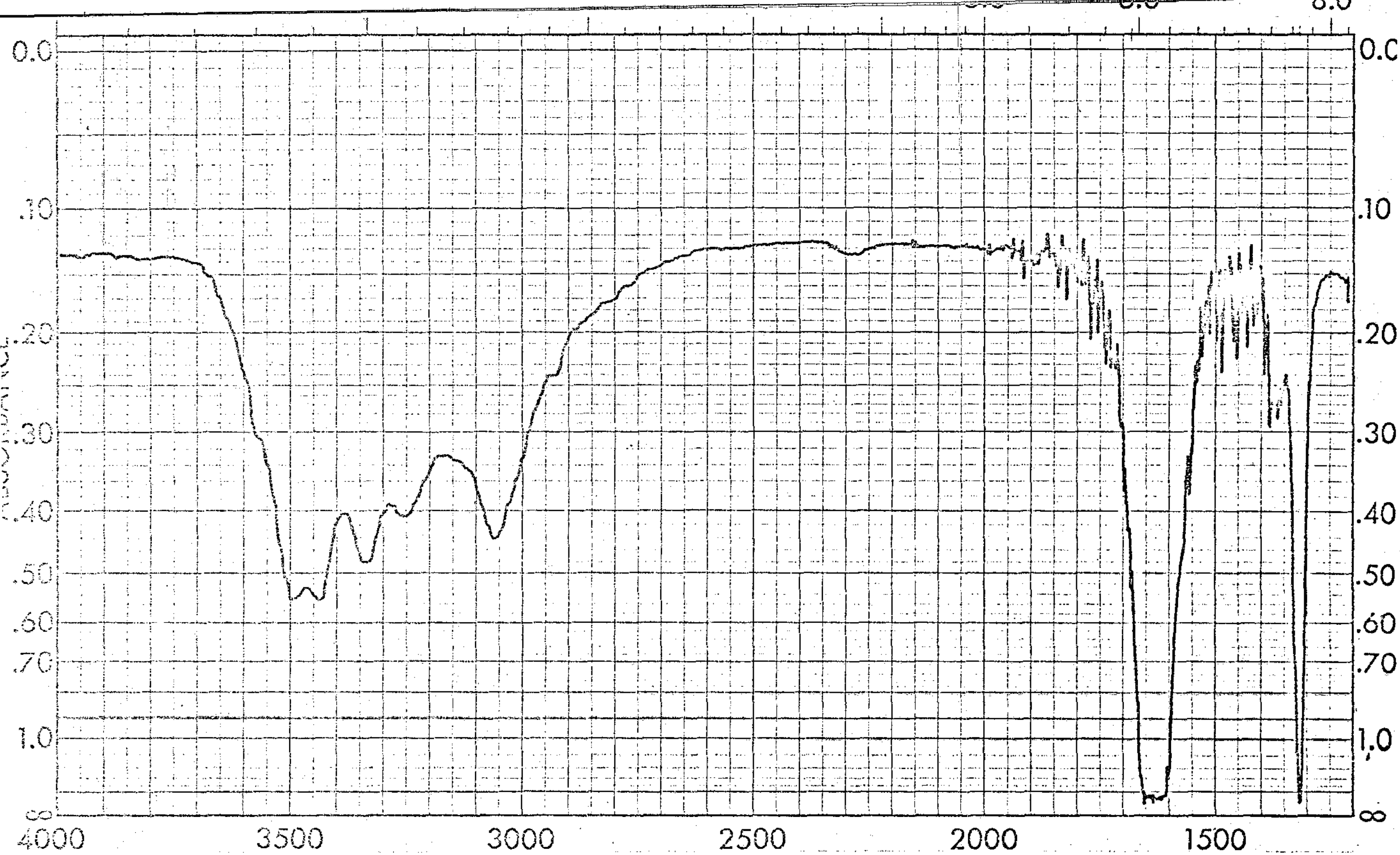
Spectrum No. 21: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



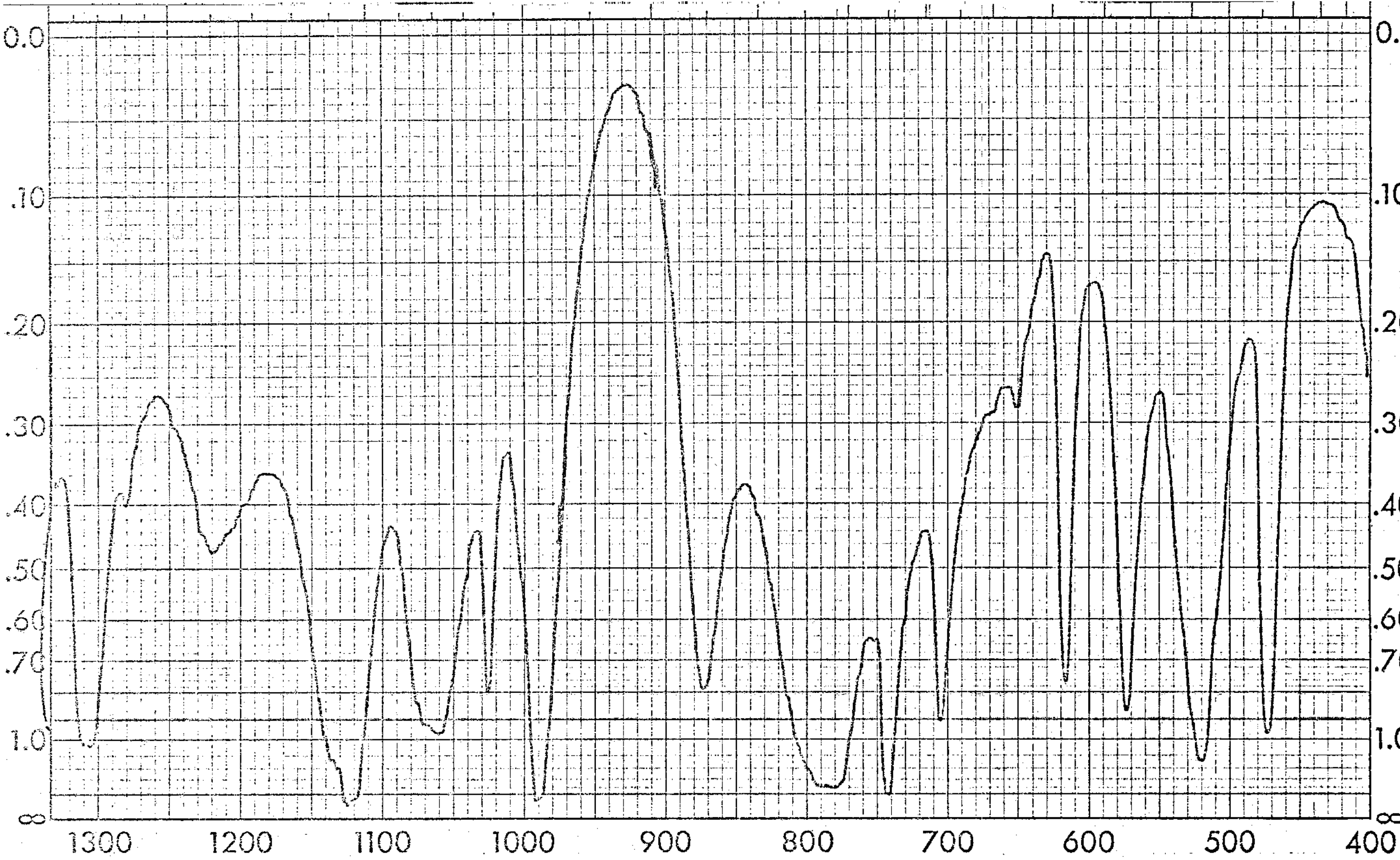
Spectrum No. 21: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



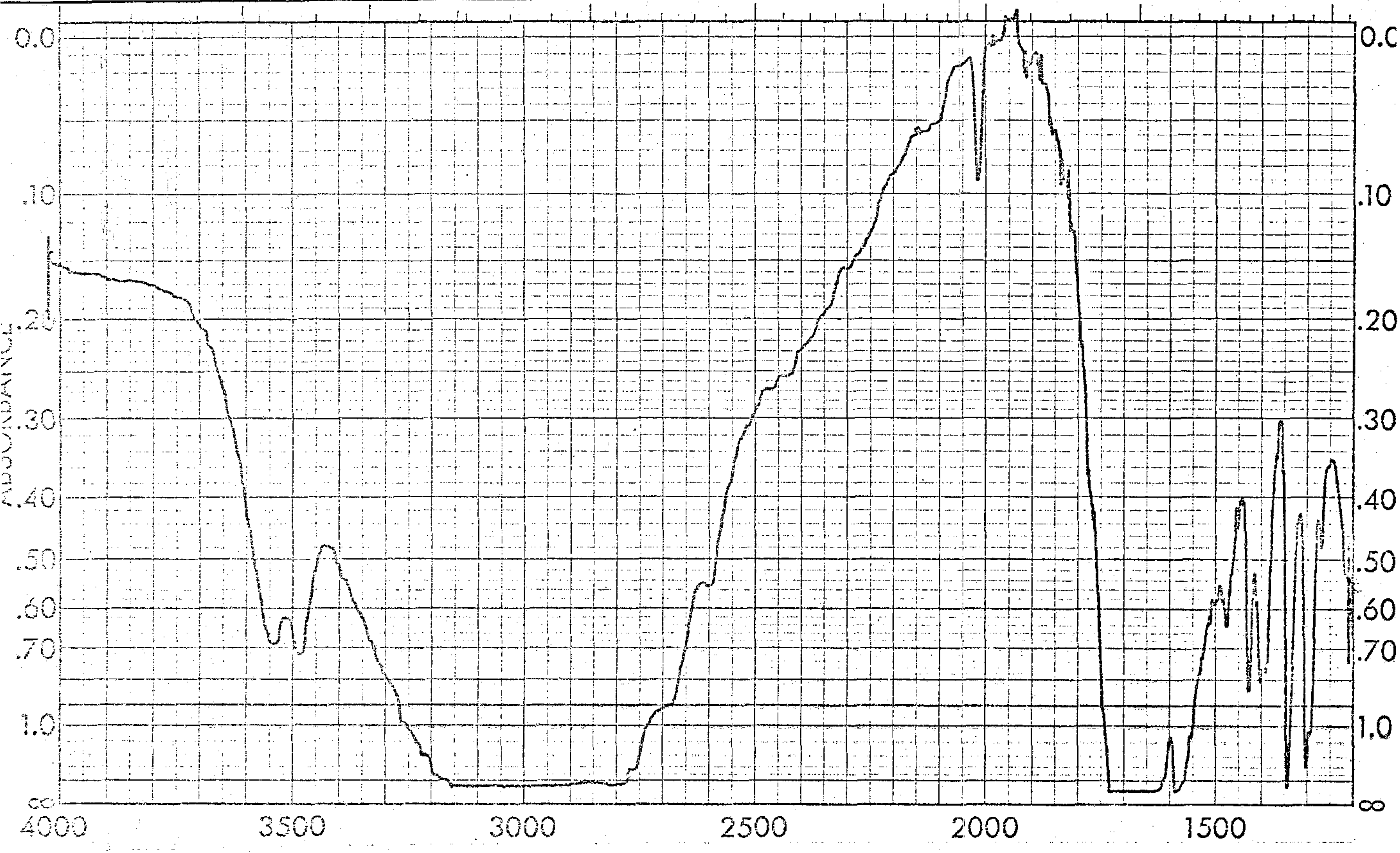
Spectrum No. 22: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$ By Transmission I.R.



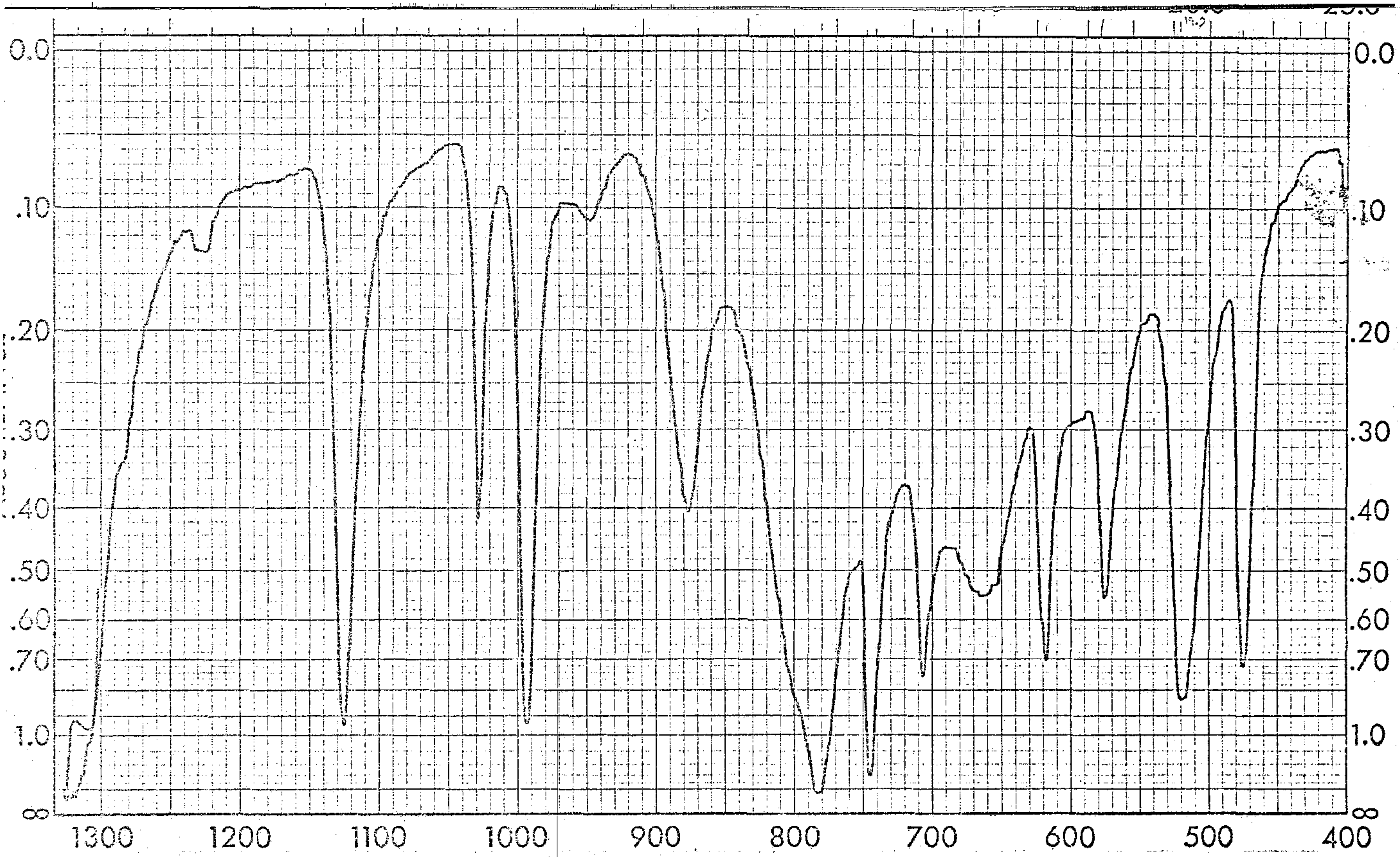
Spectrum No. 22: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$ By Transmission I.R.



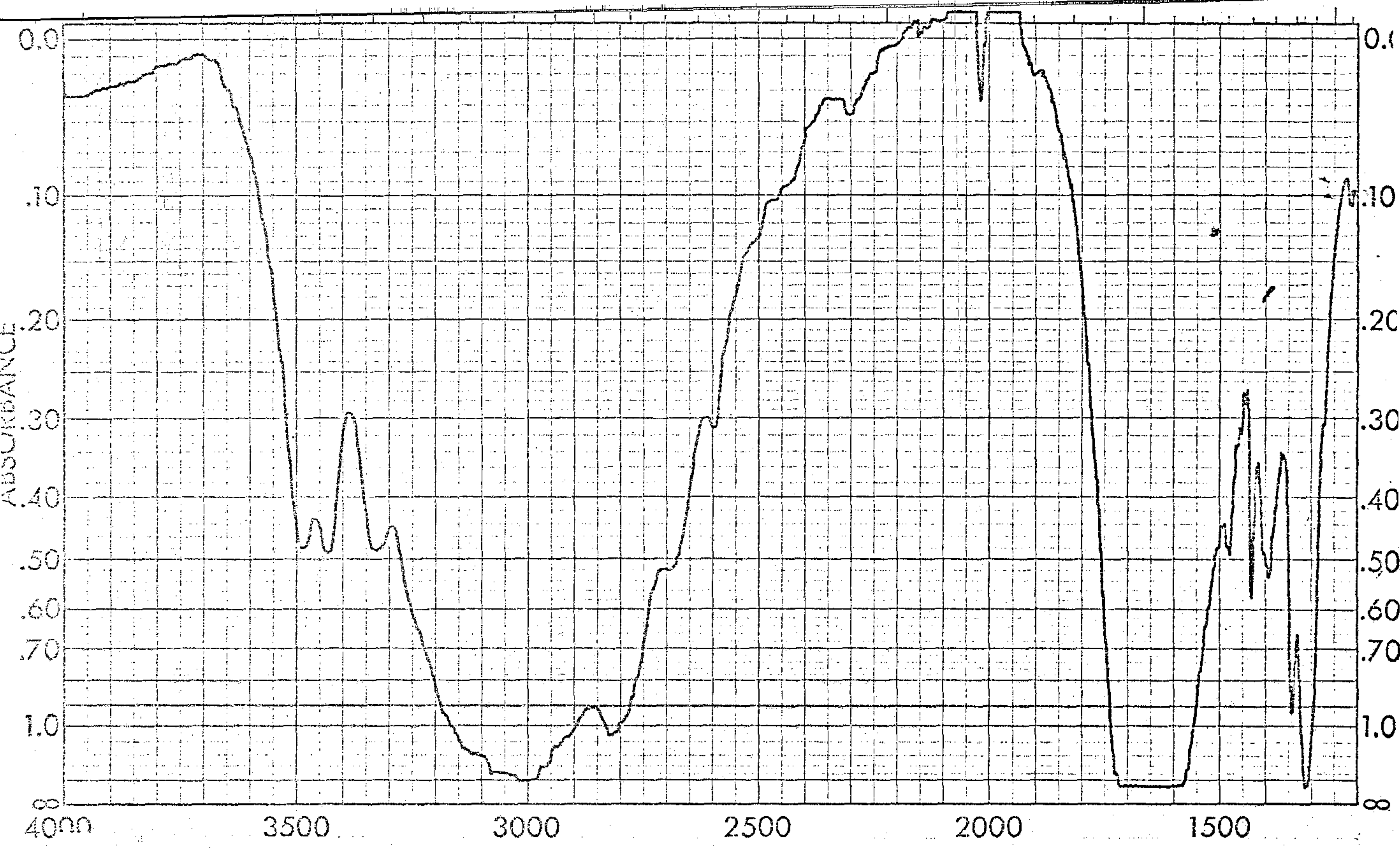
Spectrum No. 23: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.



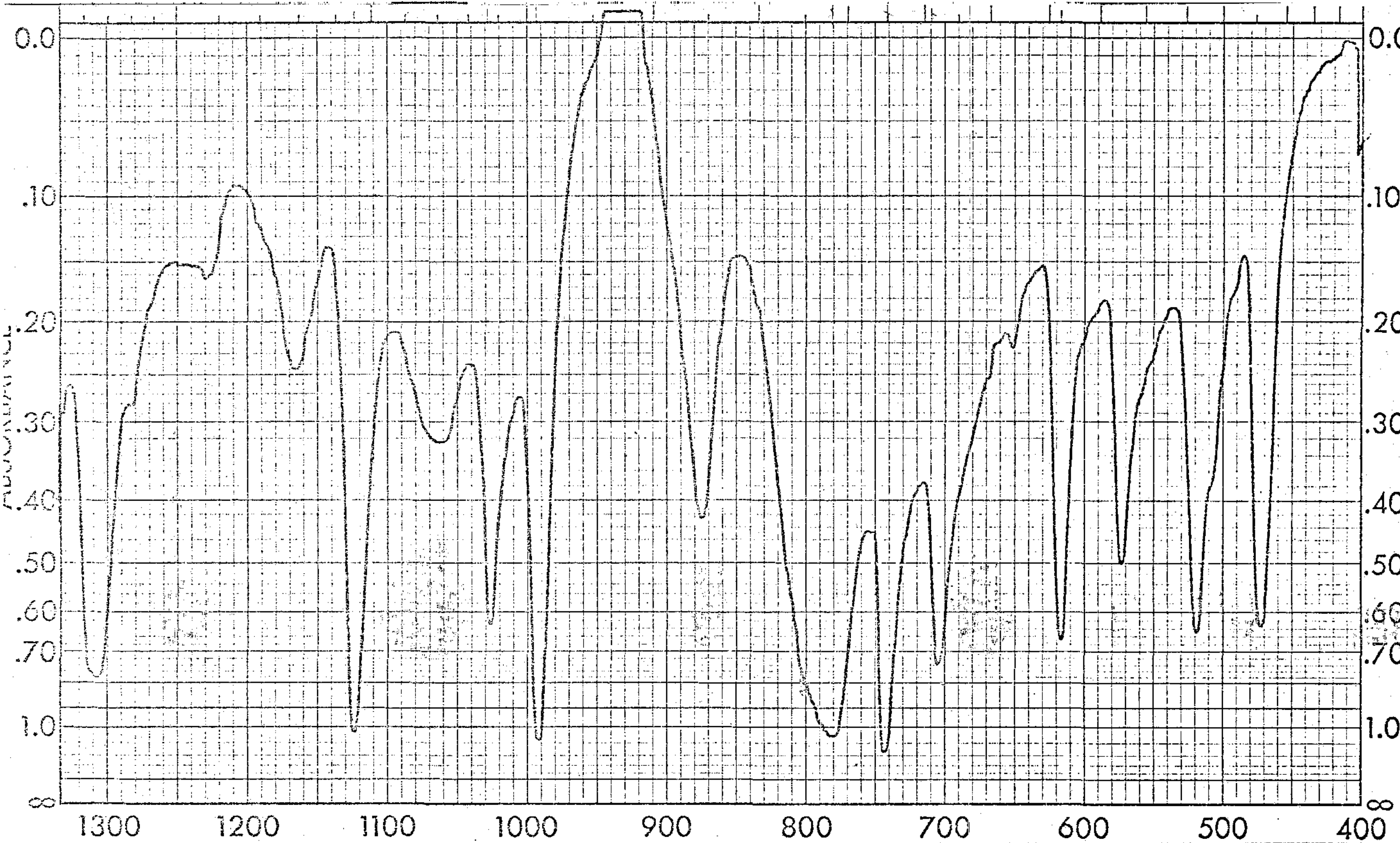
Spectrum No. 23: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.



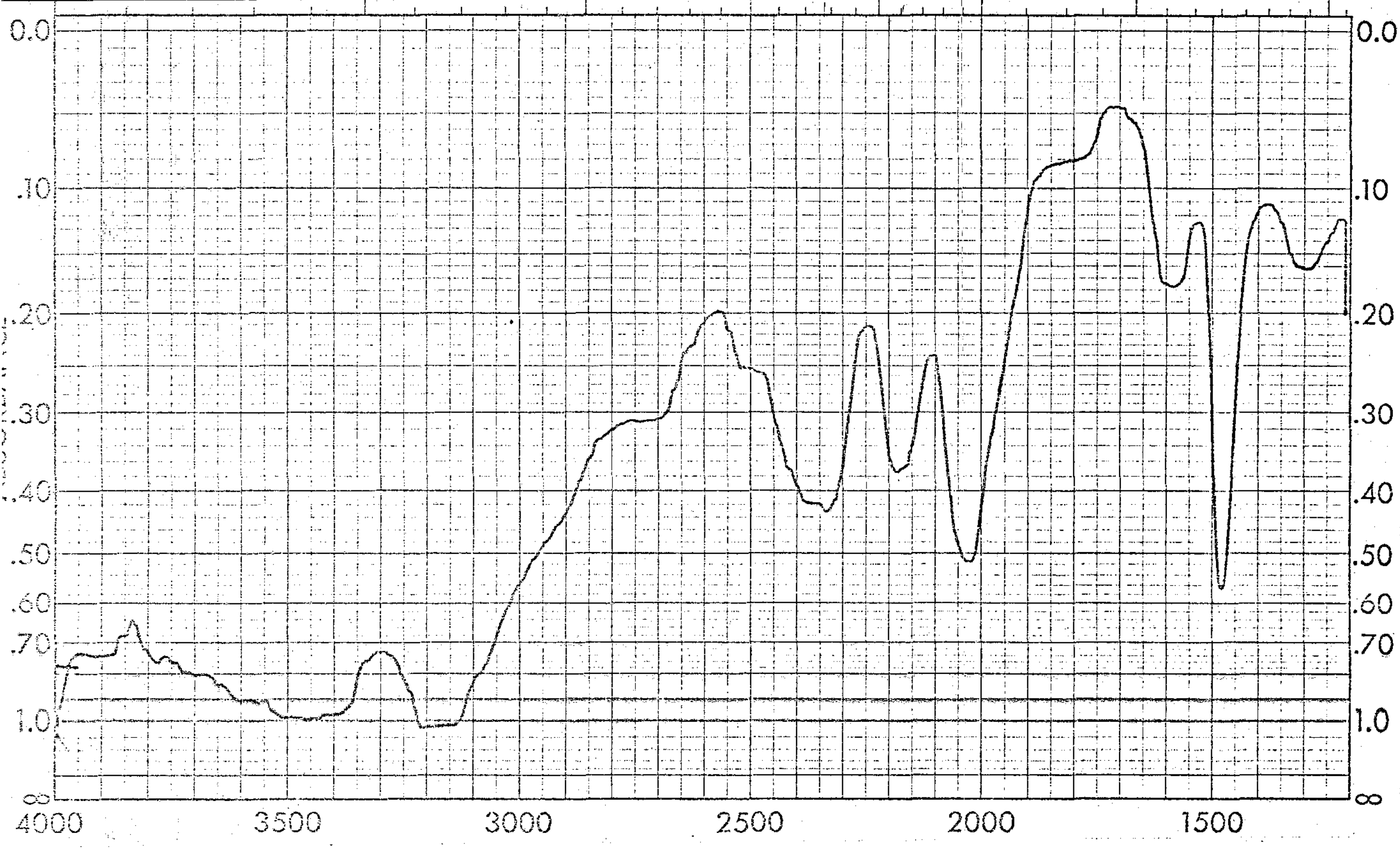
Spectrum No. 24: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ By Transmission I.R.



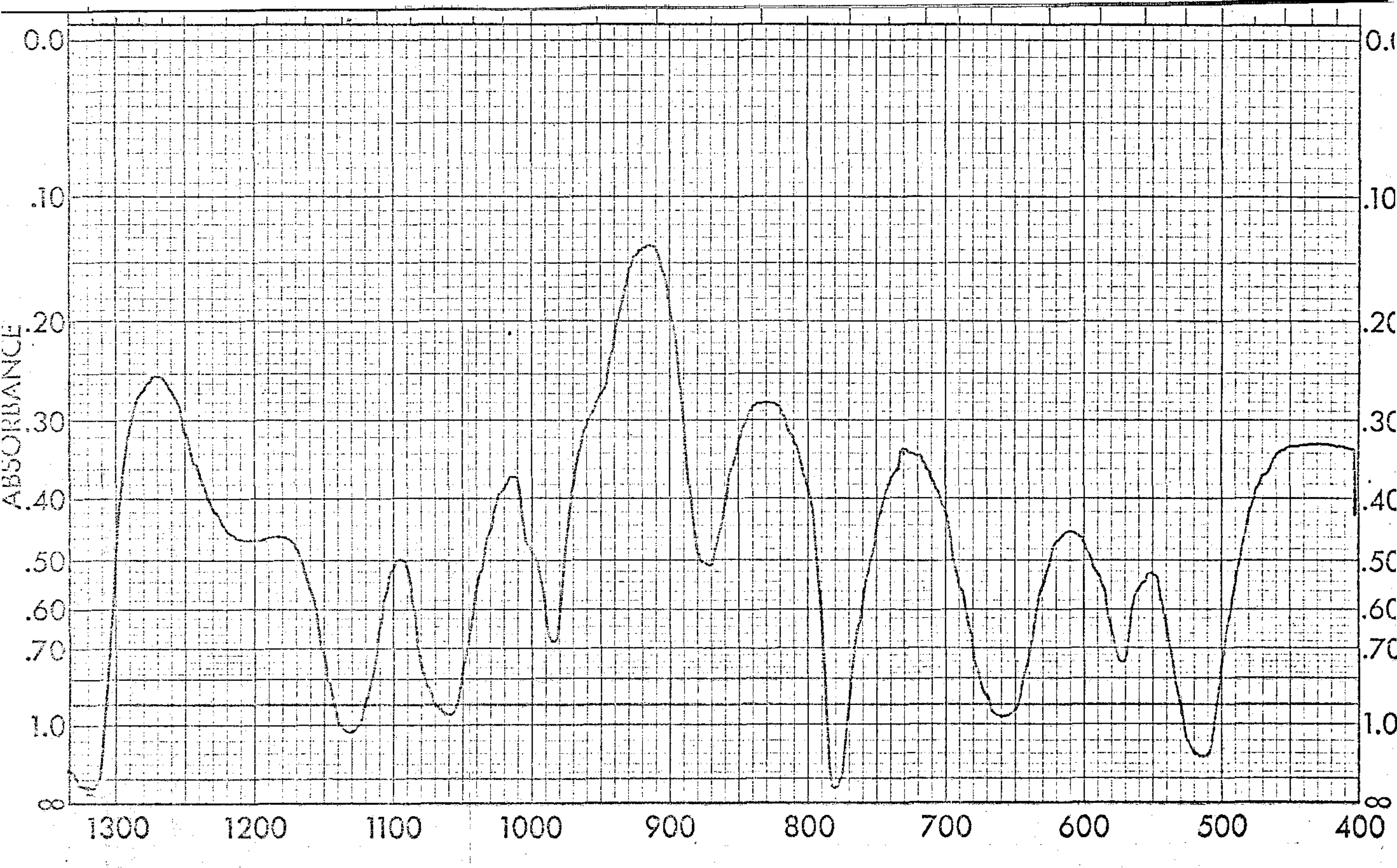
Spectrum No. 24: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$ By Transmission I.R.



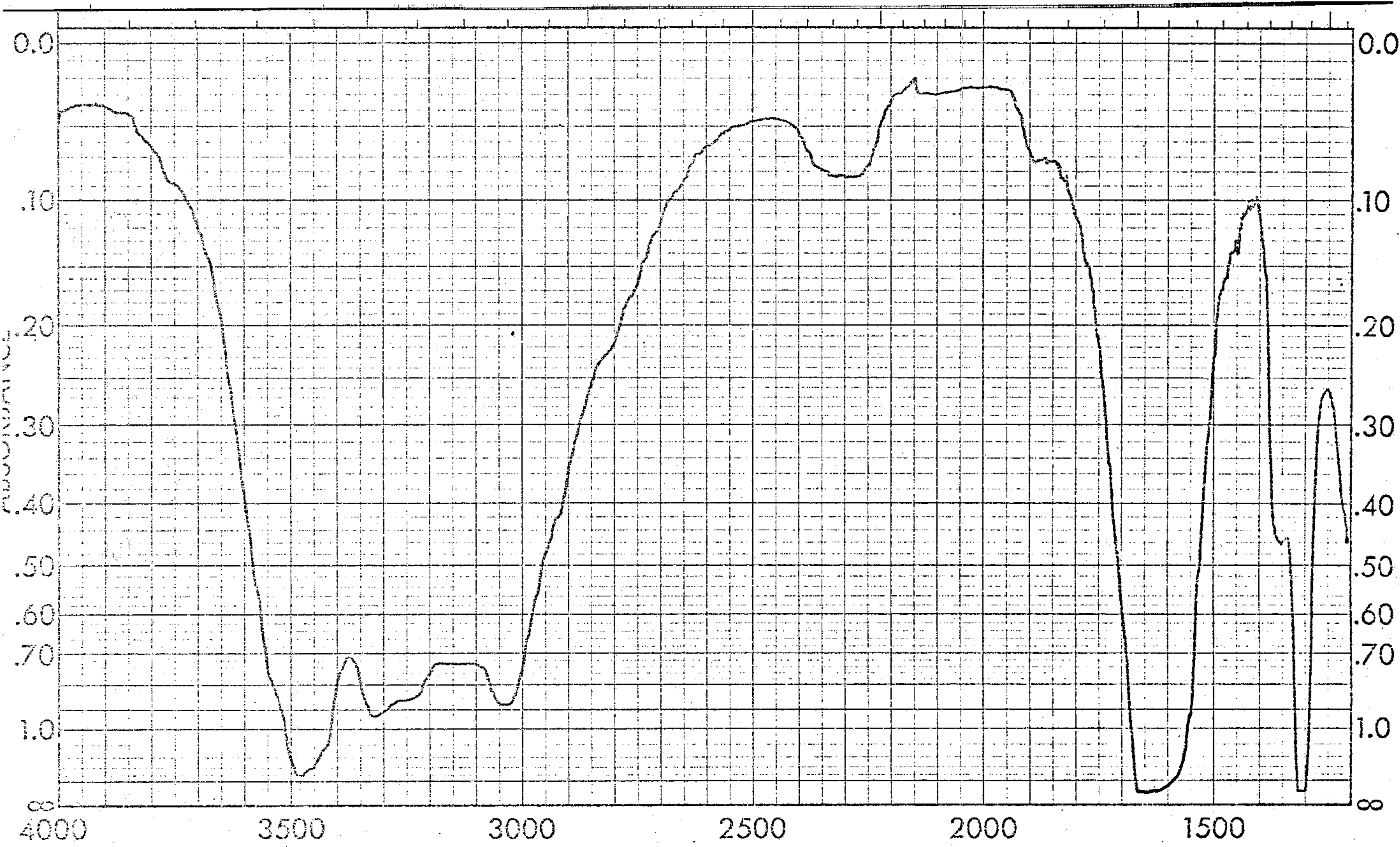
Spectrum No. 25: 50% Magnesium Phosphate, $MgHPO_4$, and 50% Uric Acid, $C_5H_4N_4O_3$ By Transmission I.R.



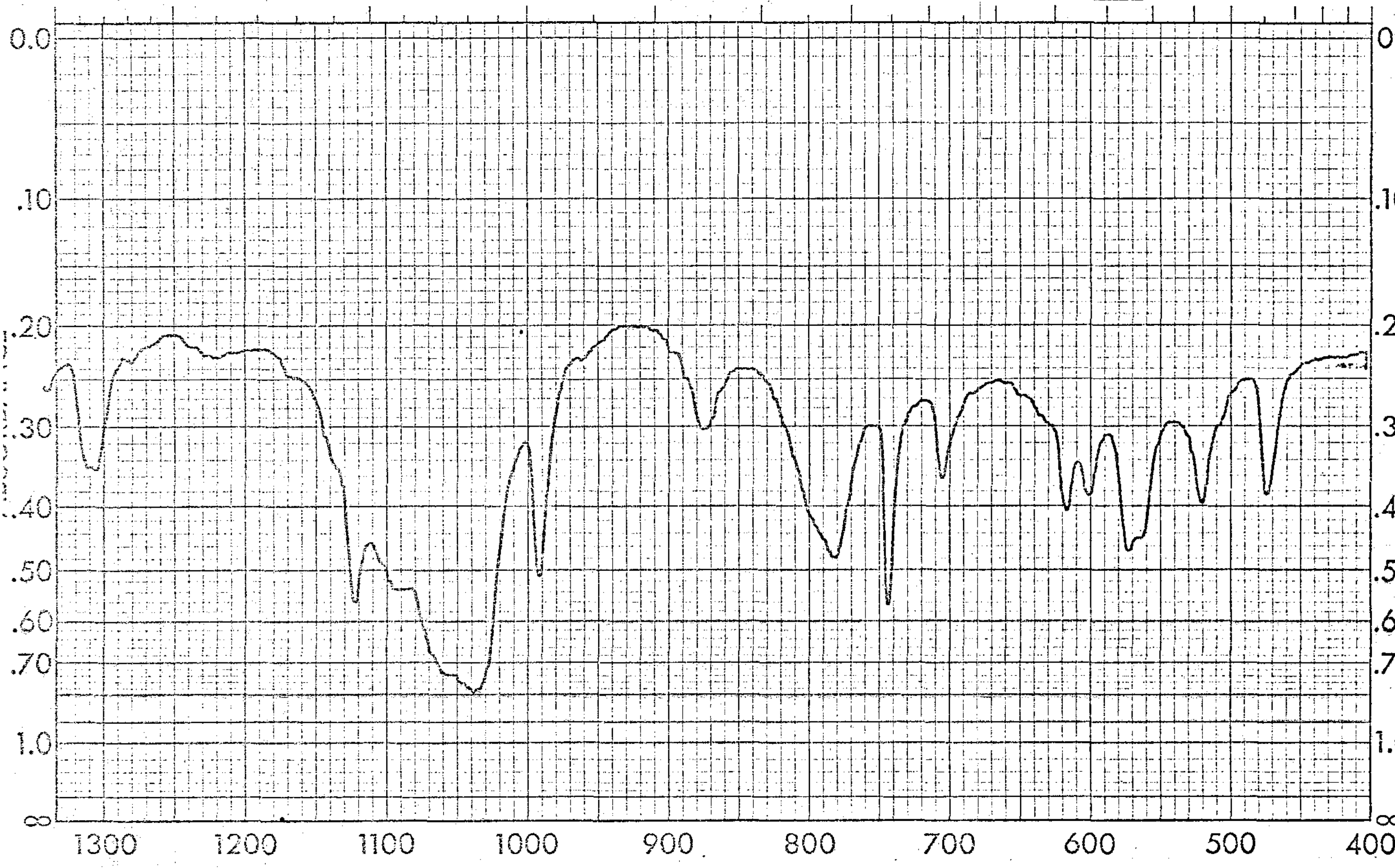
Spectrum No. 25: 50% Magnesium Phosphate, $MgHPO_4$, and 50% Uric Acid, $C_5H_4N_4O_3$ By Transmission I.R.



Spectrum No. 26: 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.

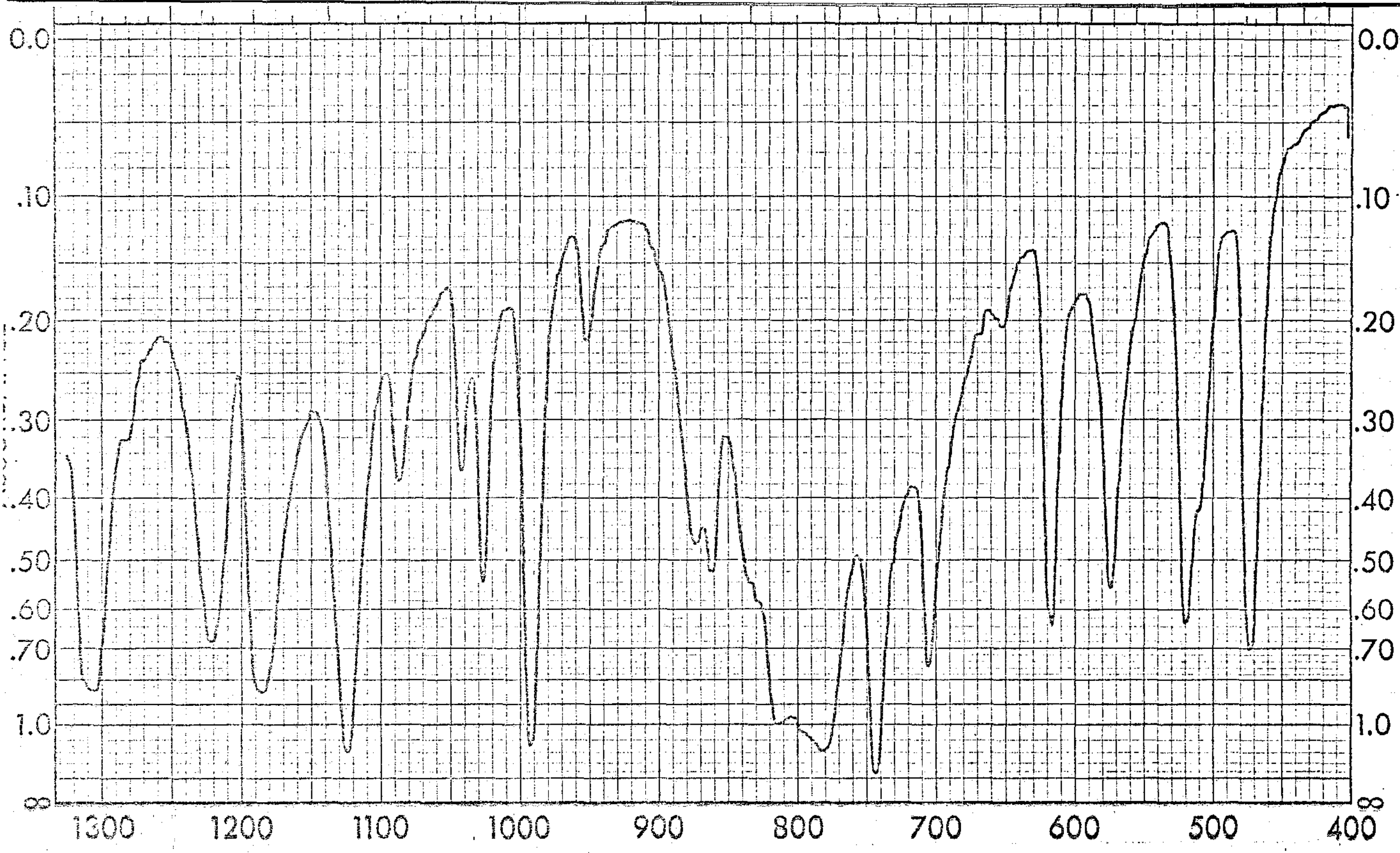


Spectrum No. 26: 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.

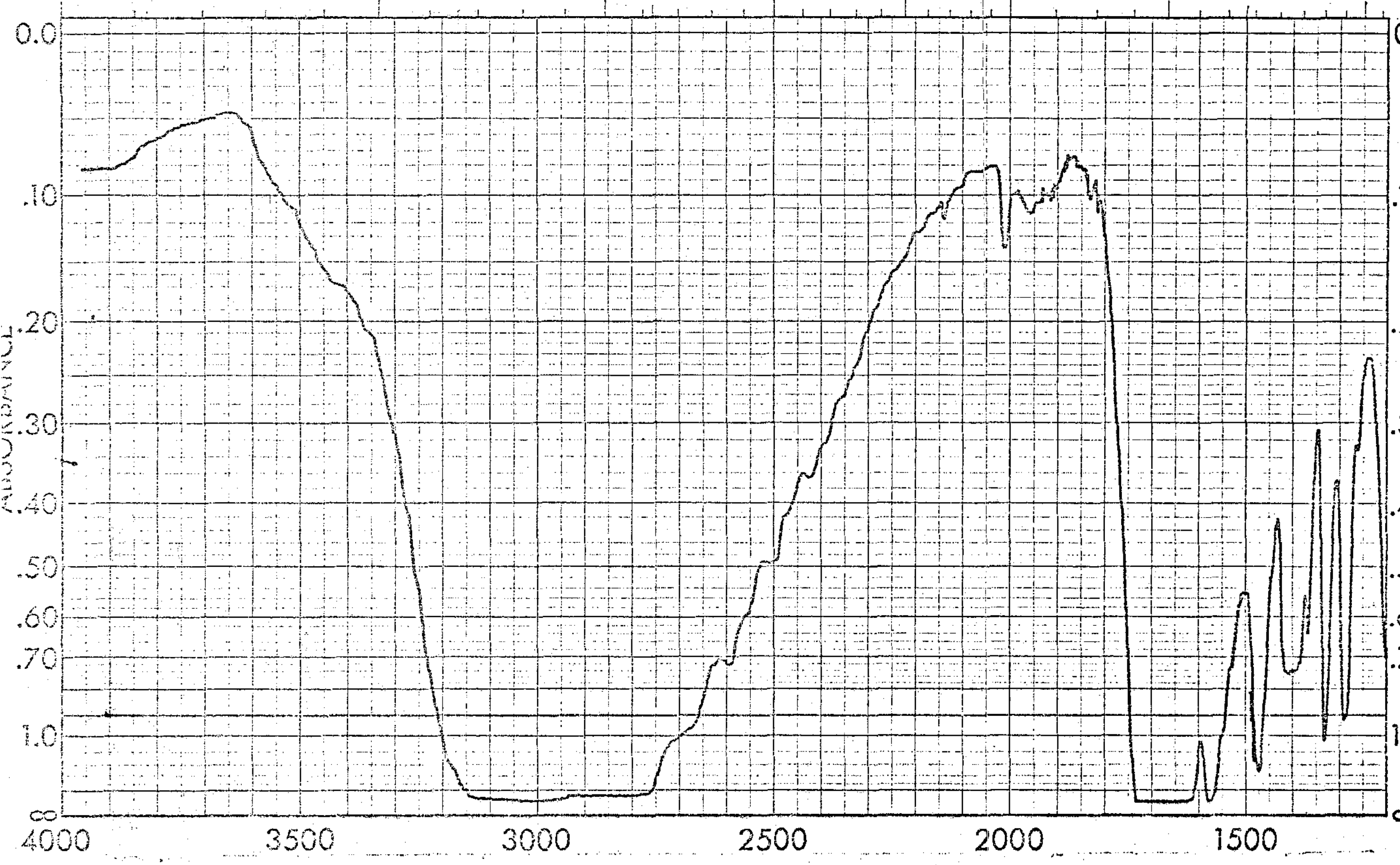


Spectrum No. 27: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$ By Transmission I.R.

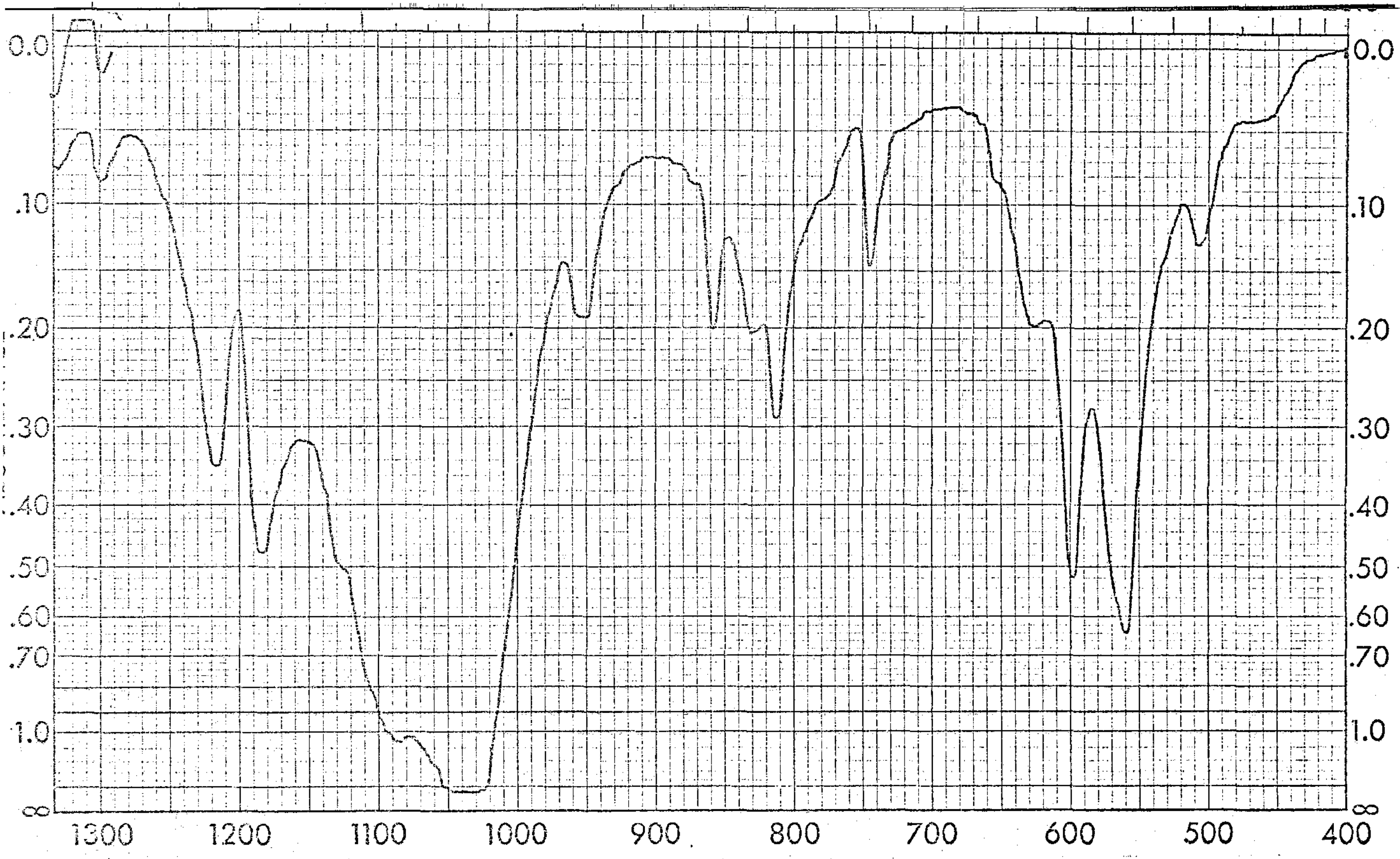
Spectrum No. 27: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$ By Transmission I.R.



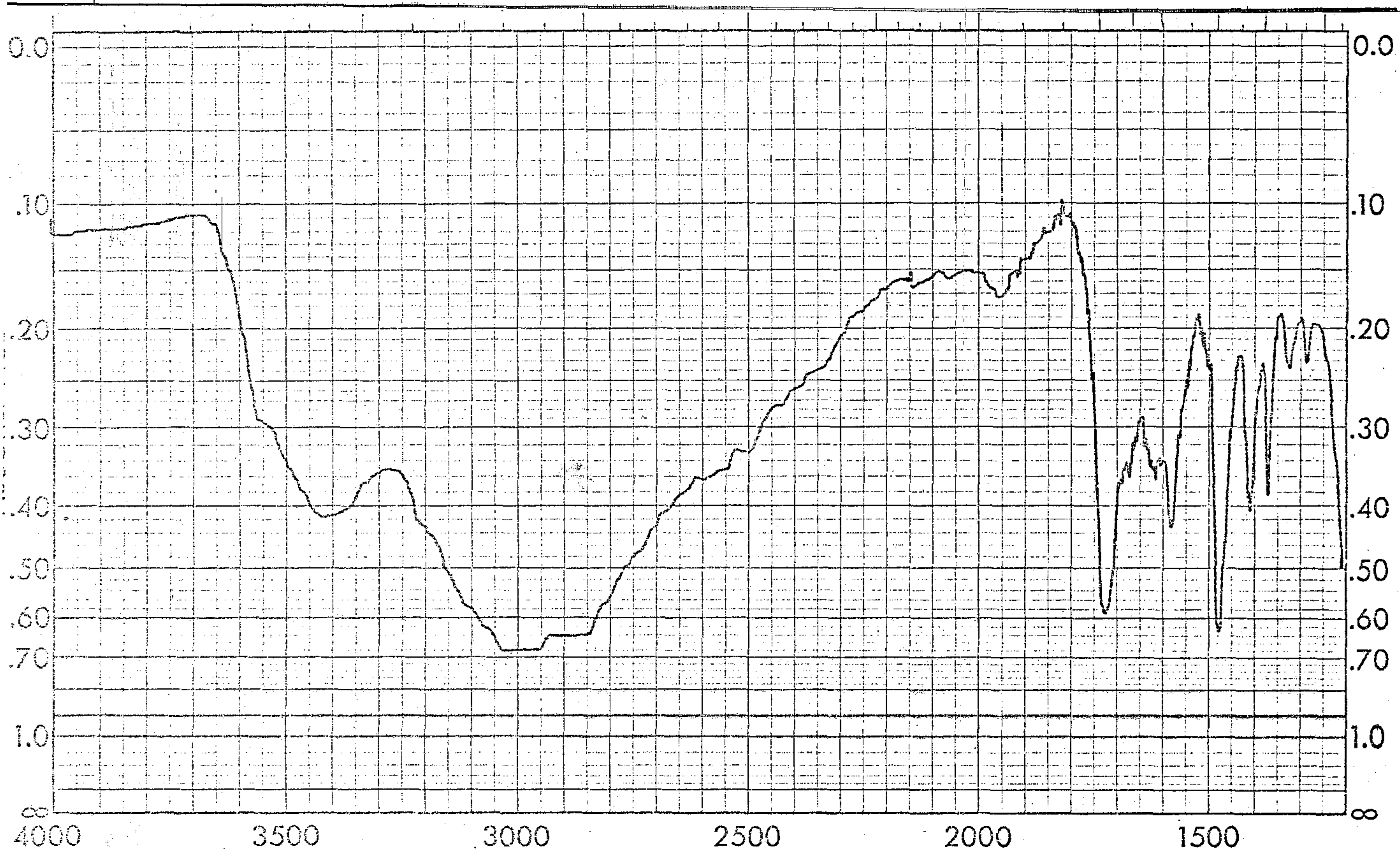
Spectrum No. 28: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Cystine, $SCH_2CH(NH_2)-COOH$ By Transmission I.R.



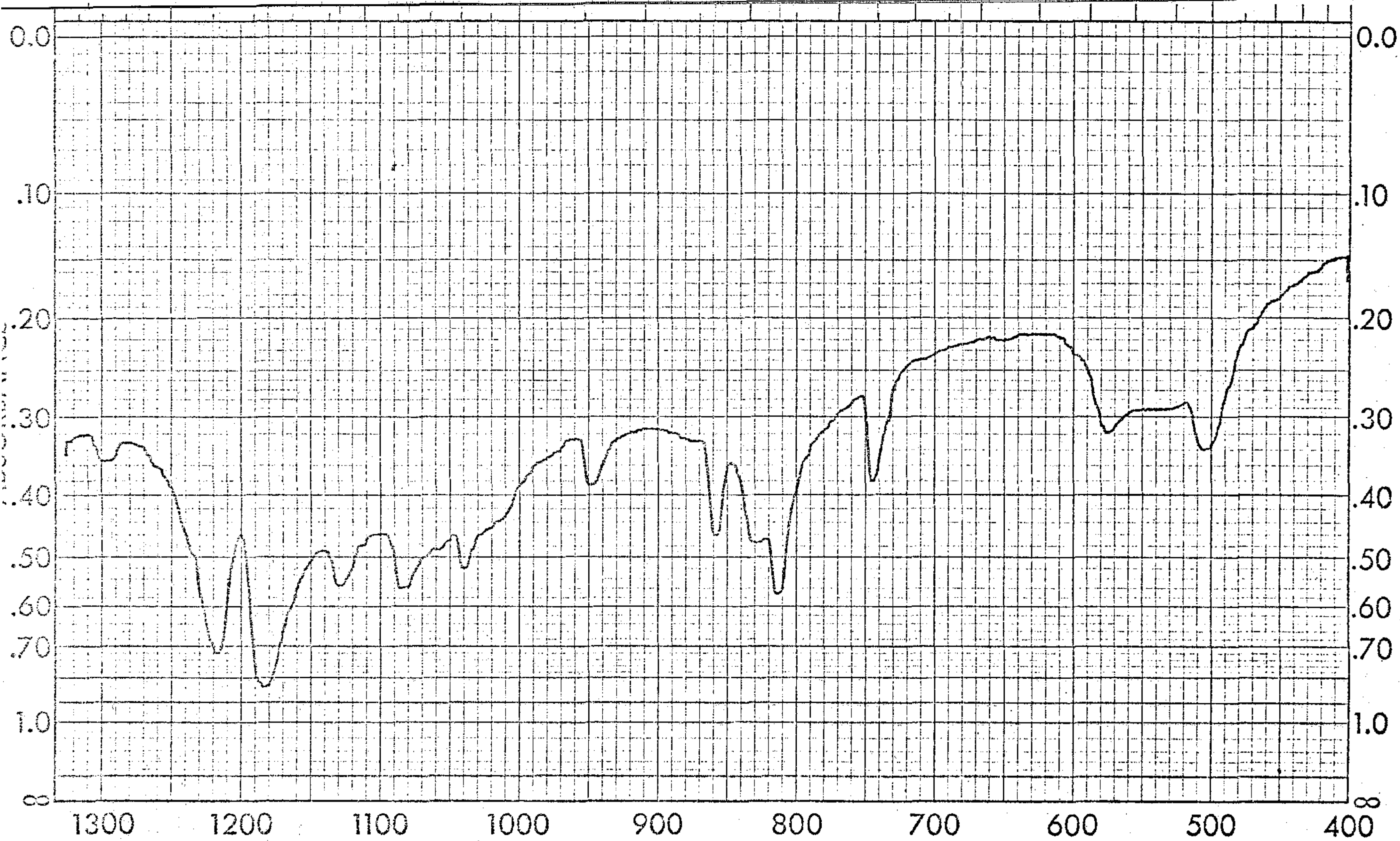
Spectrum No. 28: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Cystine, $SCH_2CH(NH_2)$-COOH By Transmission I.R.



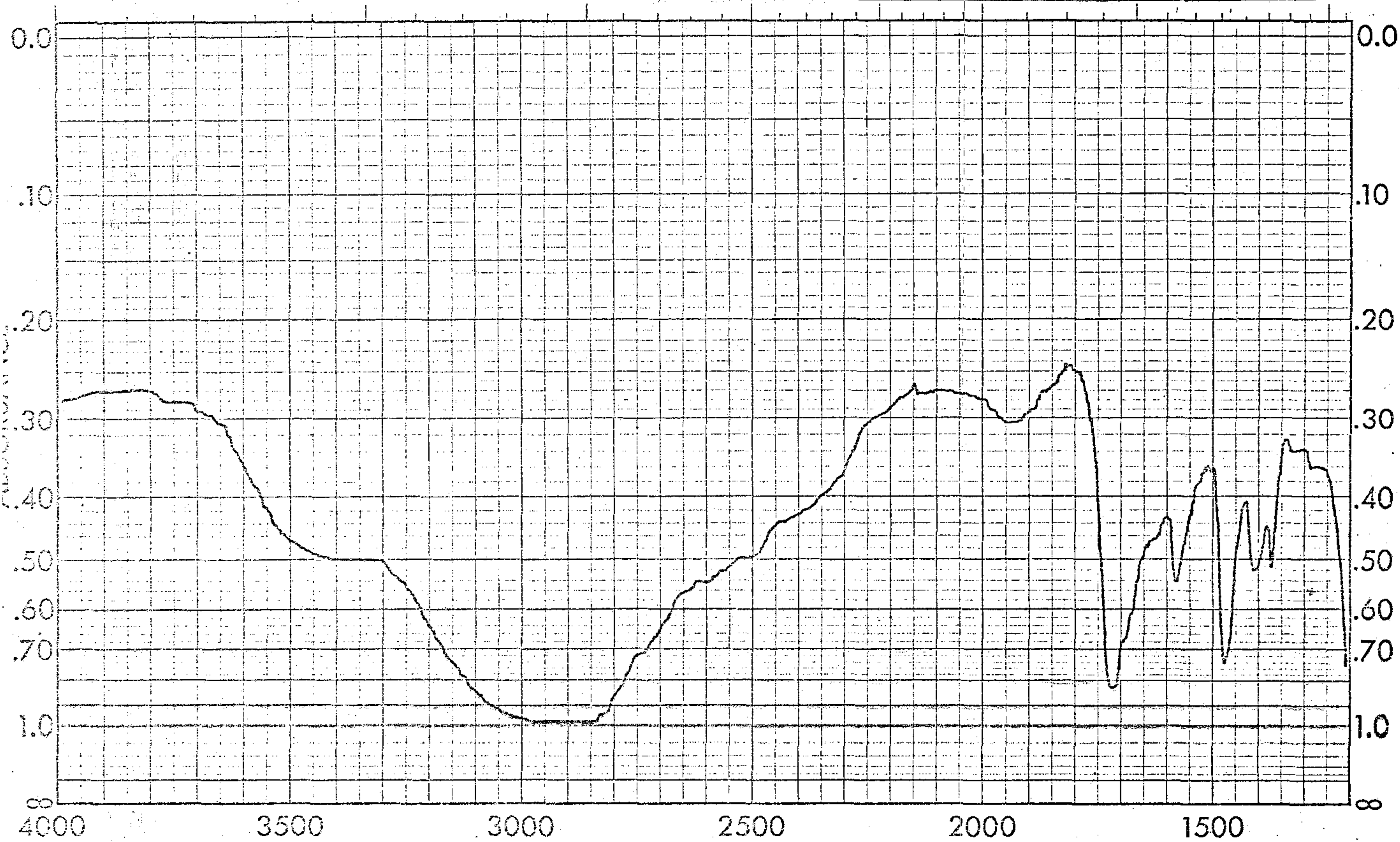
Spectrum No. 29: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50% Cystine, $SCH_2CH(NH_2)$-COOH By Transmission I.R.



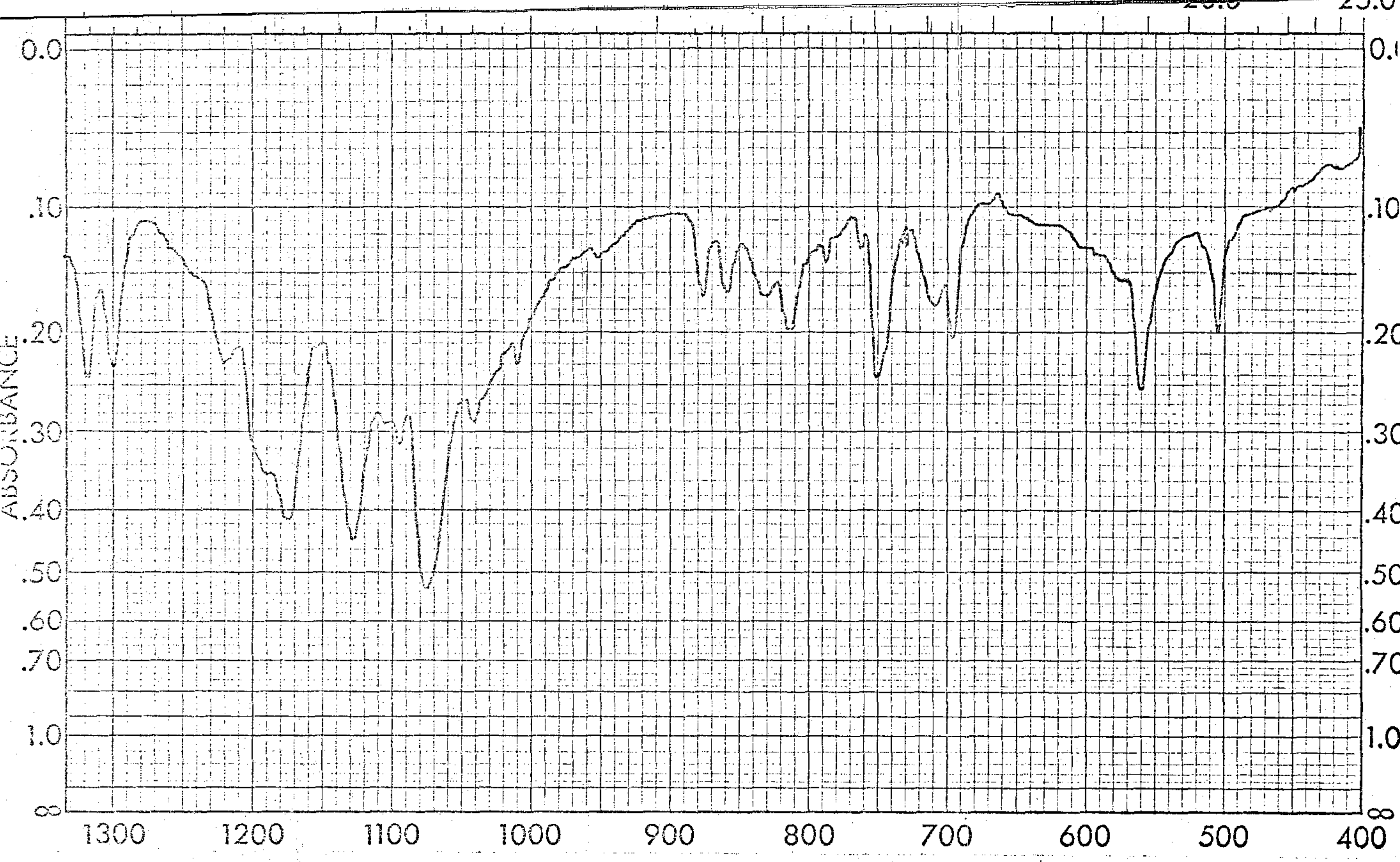
Spectrum No. 29: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50% Cystine, $SCH_2CH(NH_2)$-COOH By Transmission I.R.



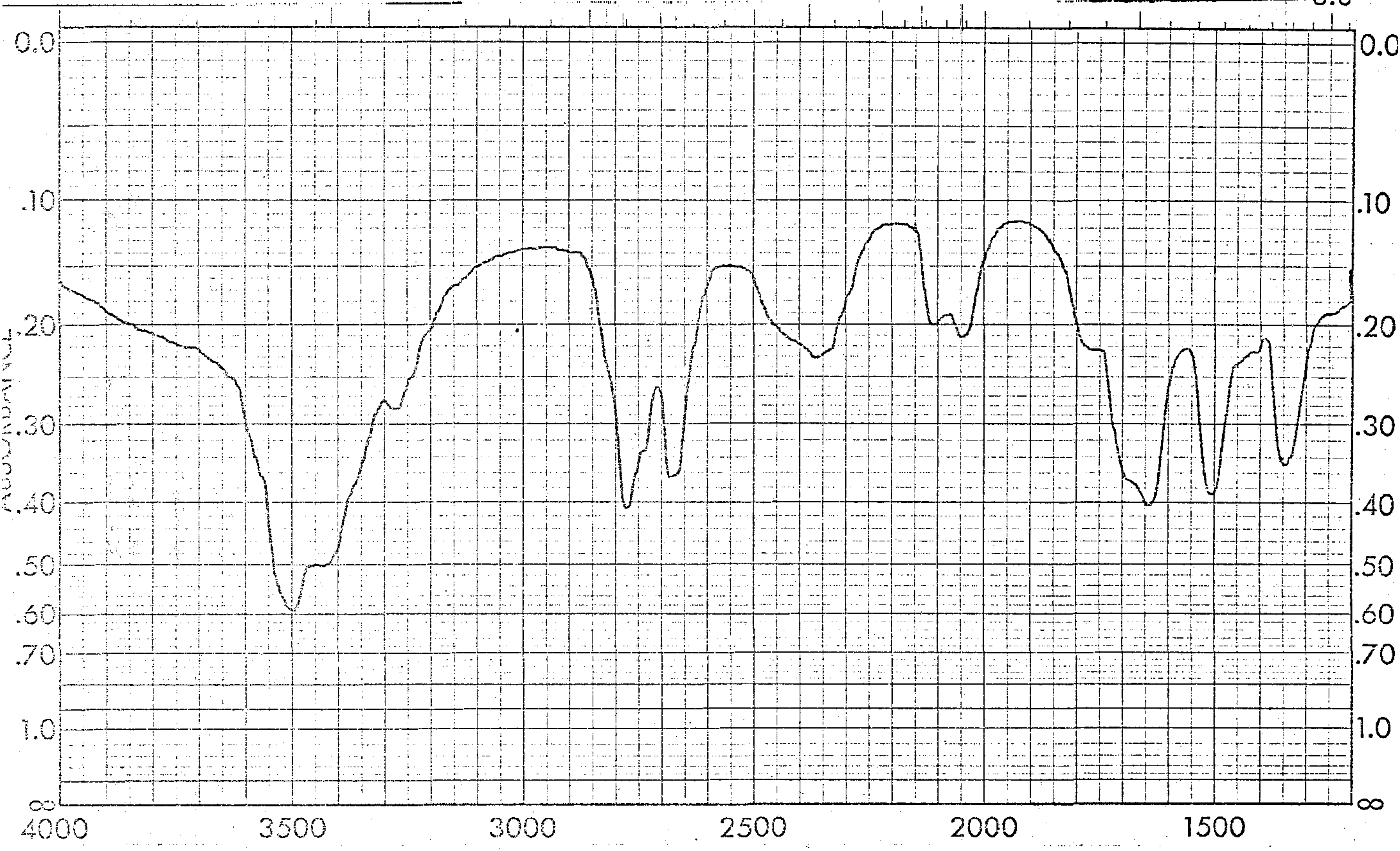
Spectrum No. 30: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 50% Cystine, $SCH_2CH(NH_2)$-COOH By Transmission I.R.



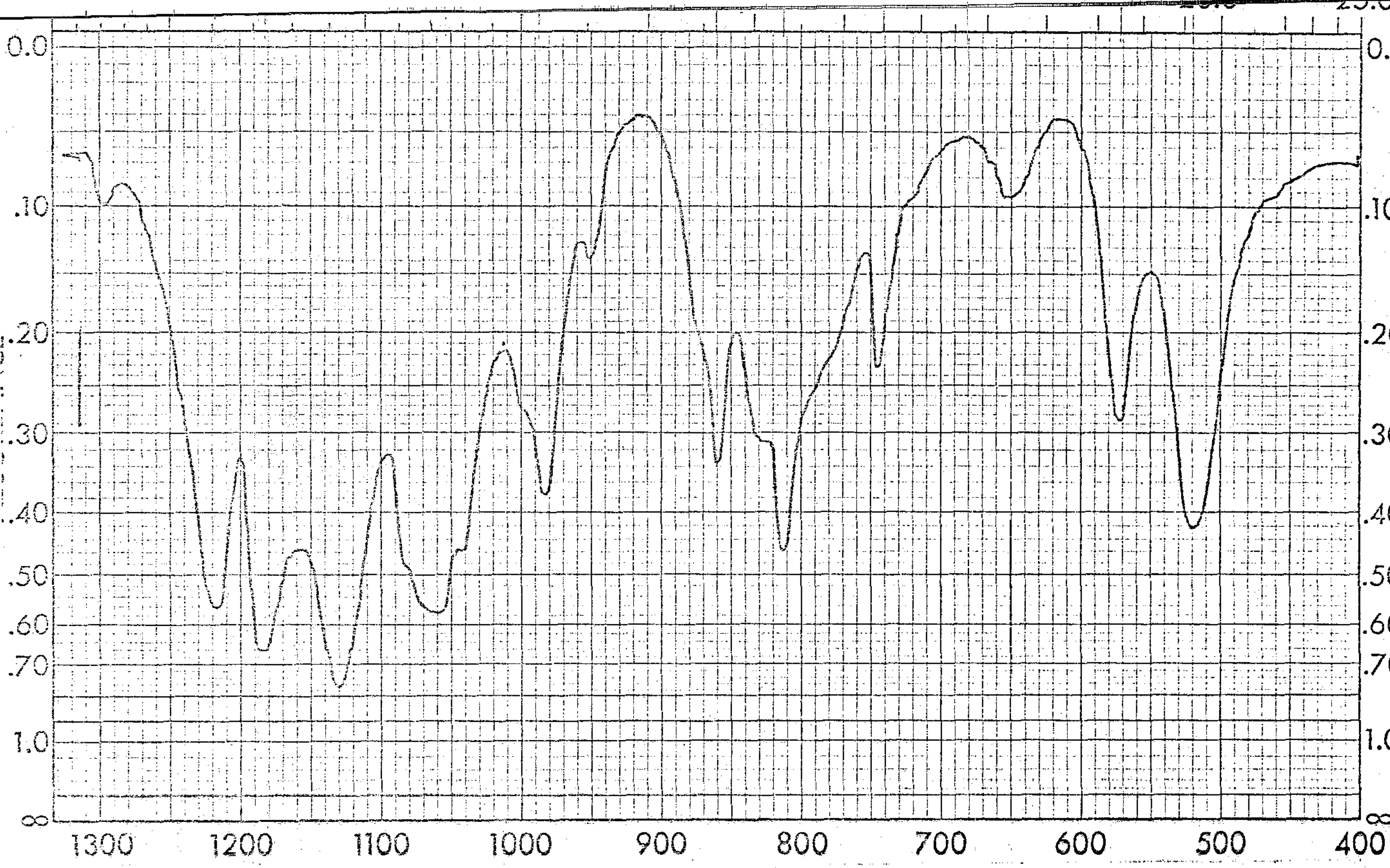
Spectrum No. 30: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 50% Cystine, $SCH_2CH(NH_2)$-COOH By Transmission I.R.



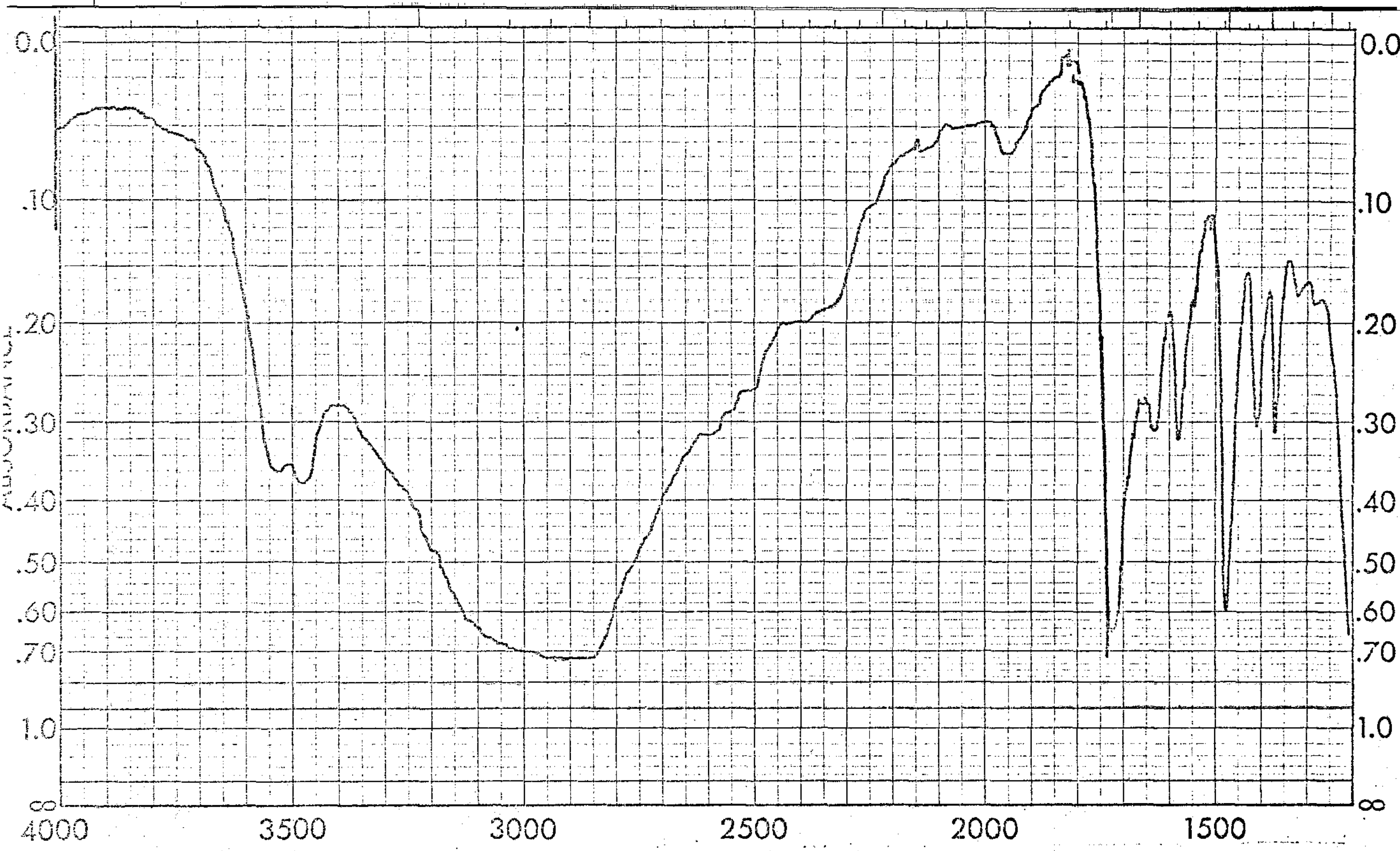
Spectrum No. 31: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Cystine, $SCH_2CH(NH_2)$-COOH By Transmission I.R.



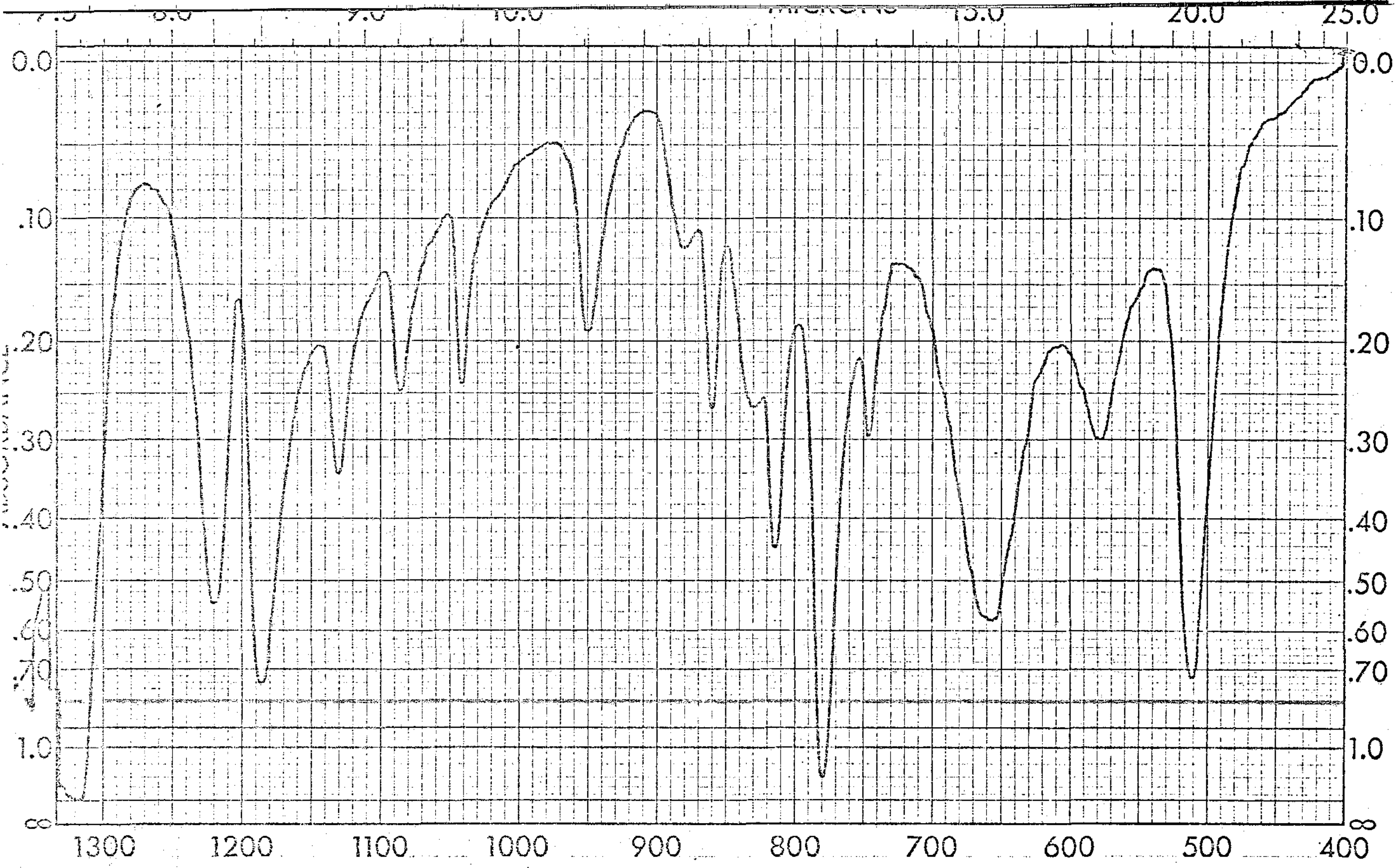
Spectrum No. 31: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Cystine, $SCH_2CH(NH_2)$-COOH By Transmission I.R.



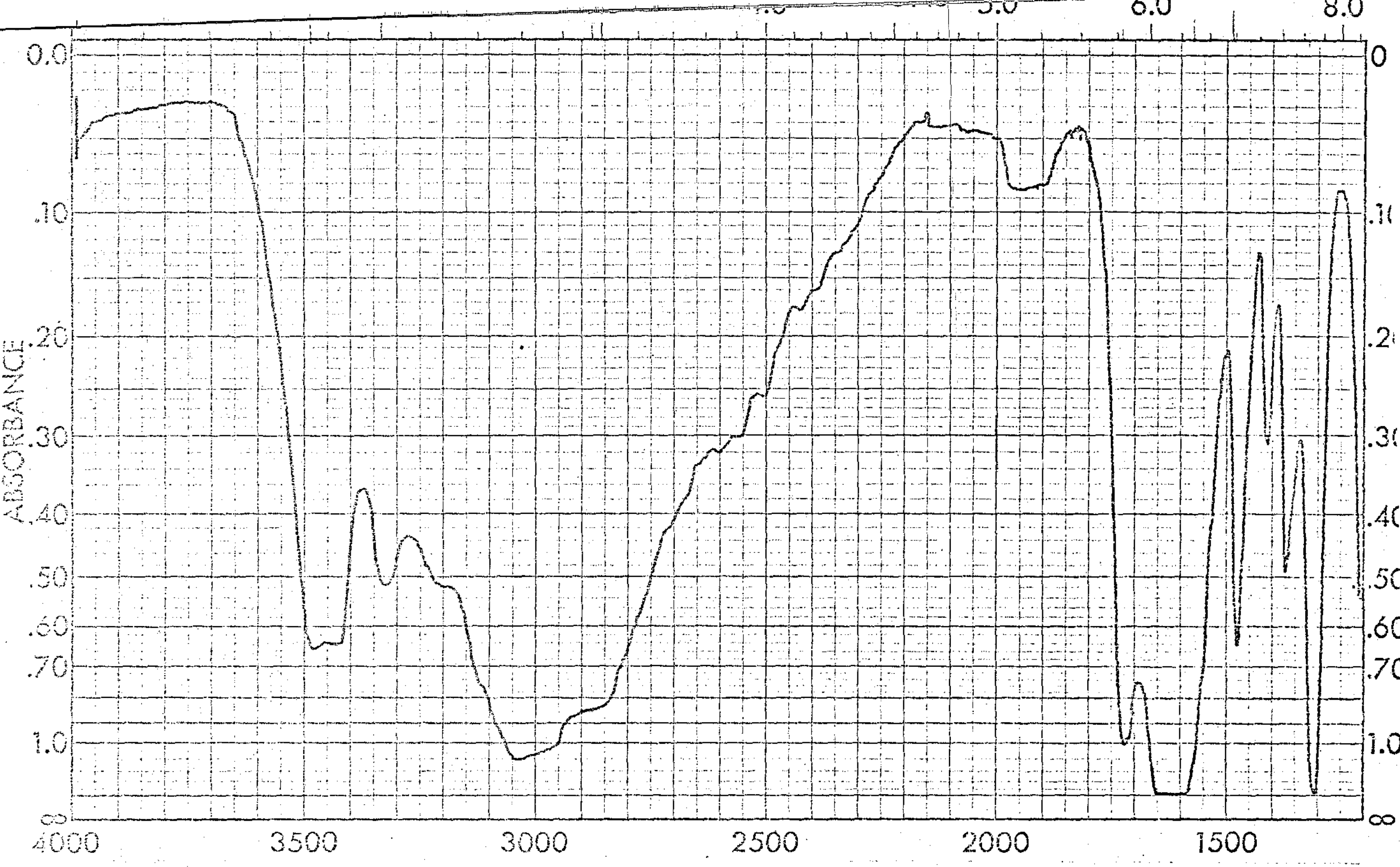
Spectrum No. 32: 50% Cystine, $SCH_2CH(NH_2)$-COOH, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.



Spectrum No. 32: 50% Cystine, $SCH_2CH(NH_2)$-COOH, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.

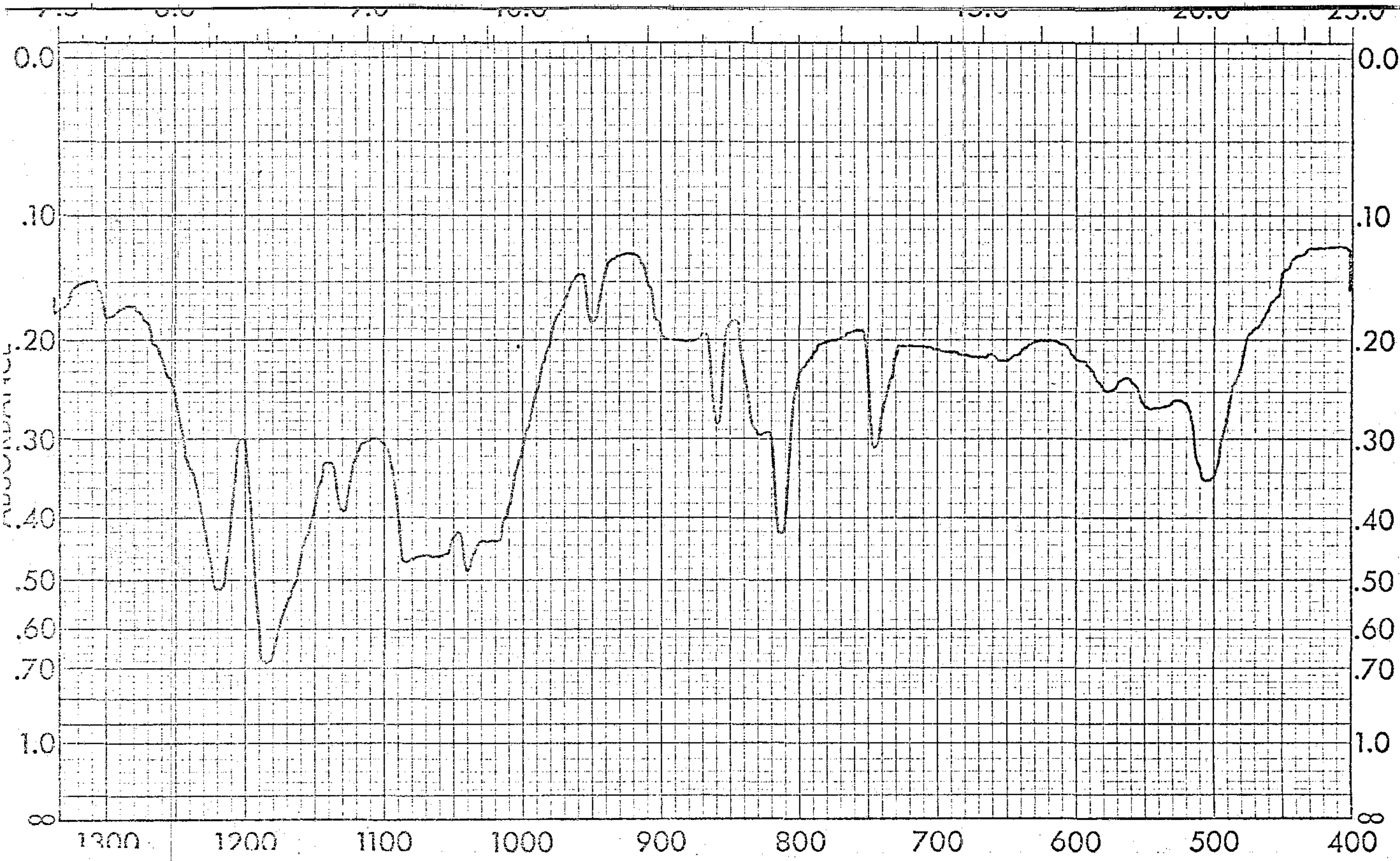


Spectrum No. 33: 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, and 50% Cystine, $SCH_2CH(NH_2)$-COOH By Transmission I.R.

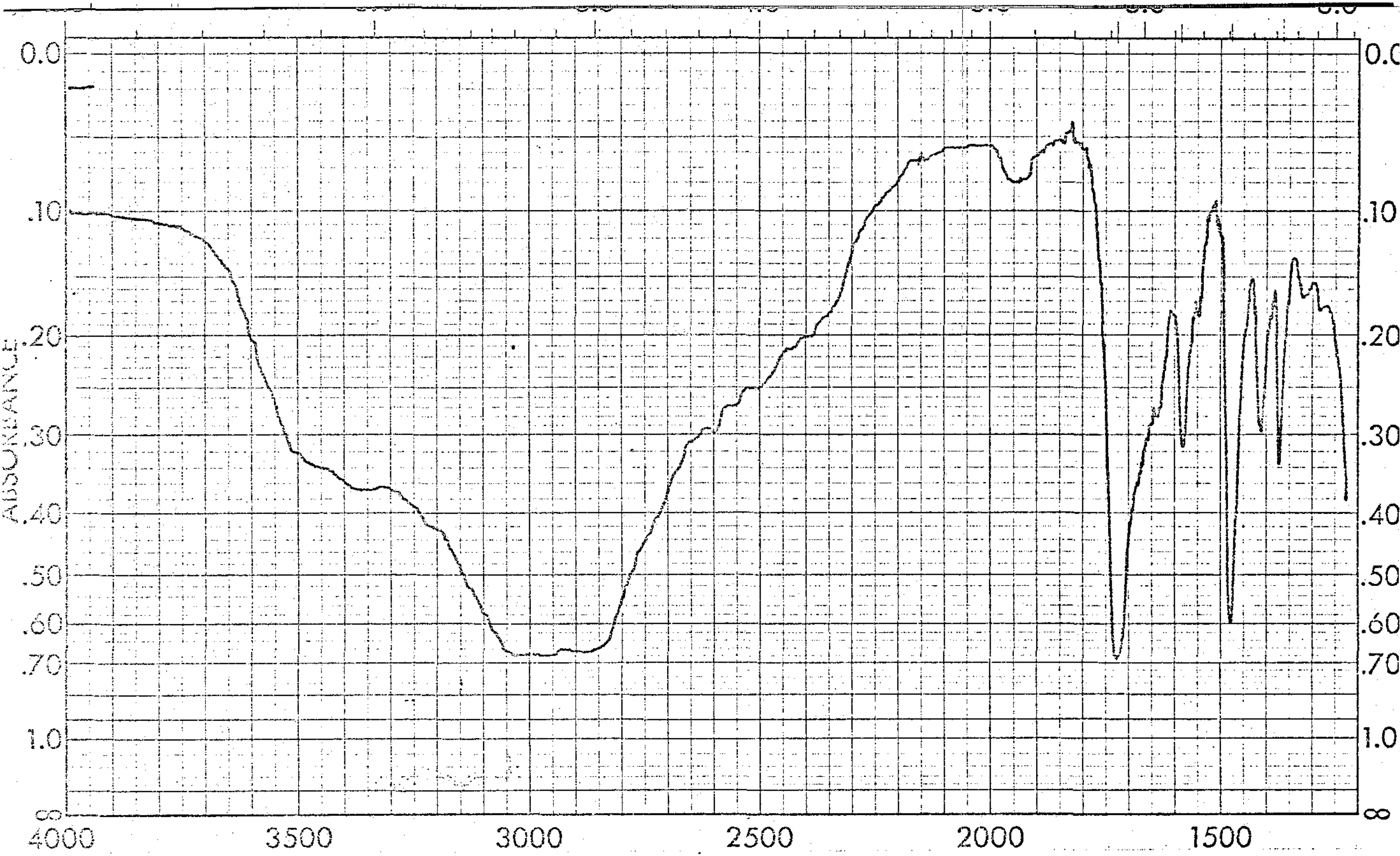


Spectrum No. 33: 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, and

50% Cystine, $SCH_2CH(NH_2)$-COOH By Transmission I.R.



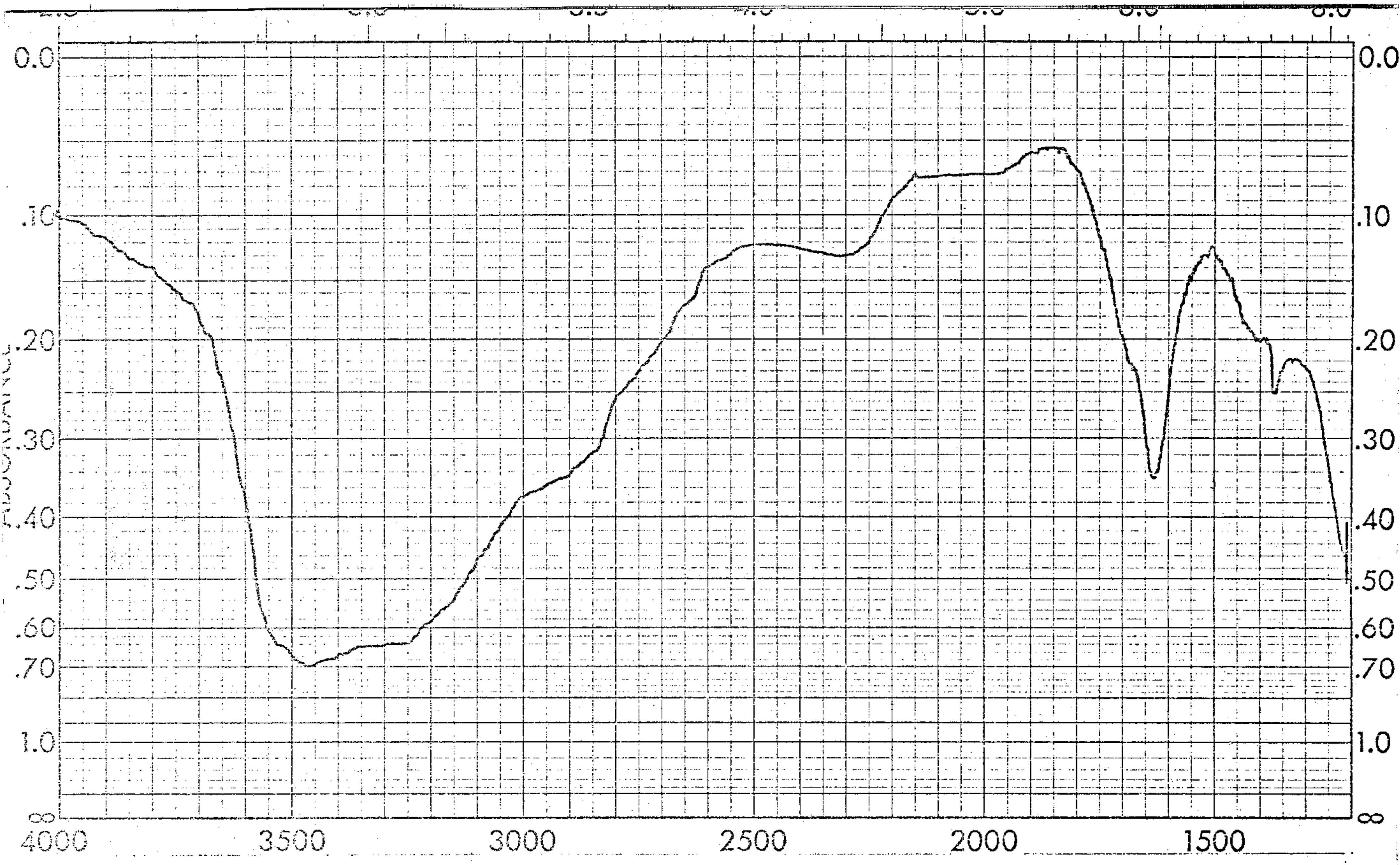
Spectrum No. 34: 50% Magnesium Phosphate, $MgHPO_4$, and 50% Cystine, $SCH_2CH(NH_2)$-COOH By Transmission I.R.



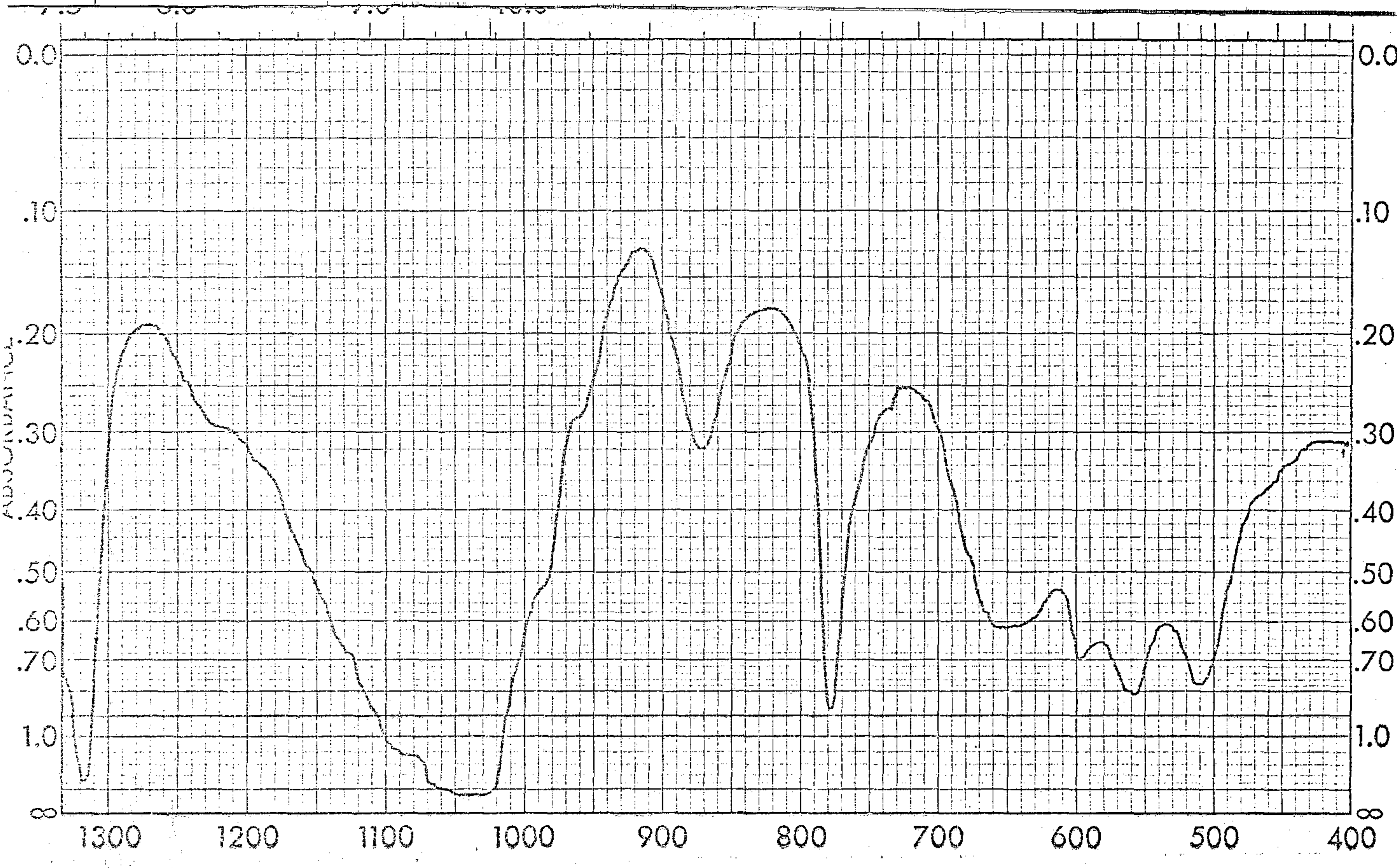
Spectrum No. 34: 50% Magnesium Phosphate, $MgHPO_4$, and 50% Cystine,

$SCH_2CH(NH_2)$-COOH By Transmission I.R.

Spectrum No. 35: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.

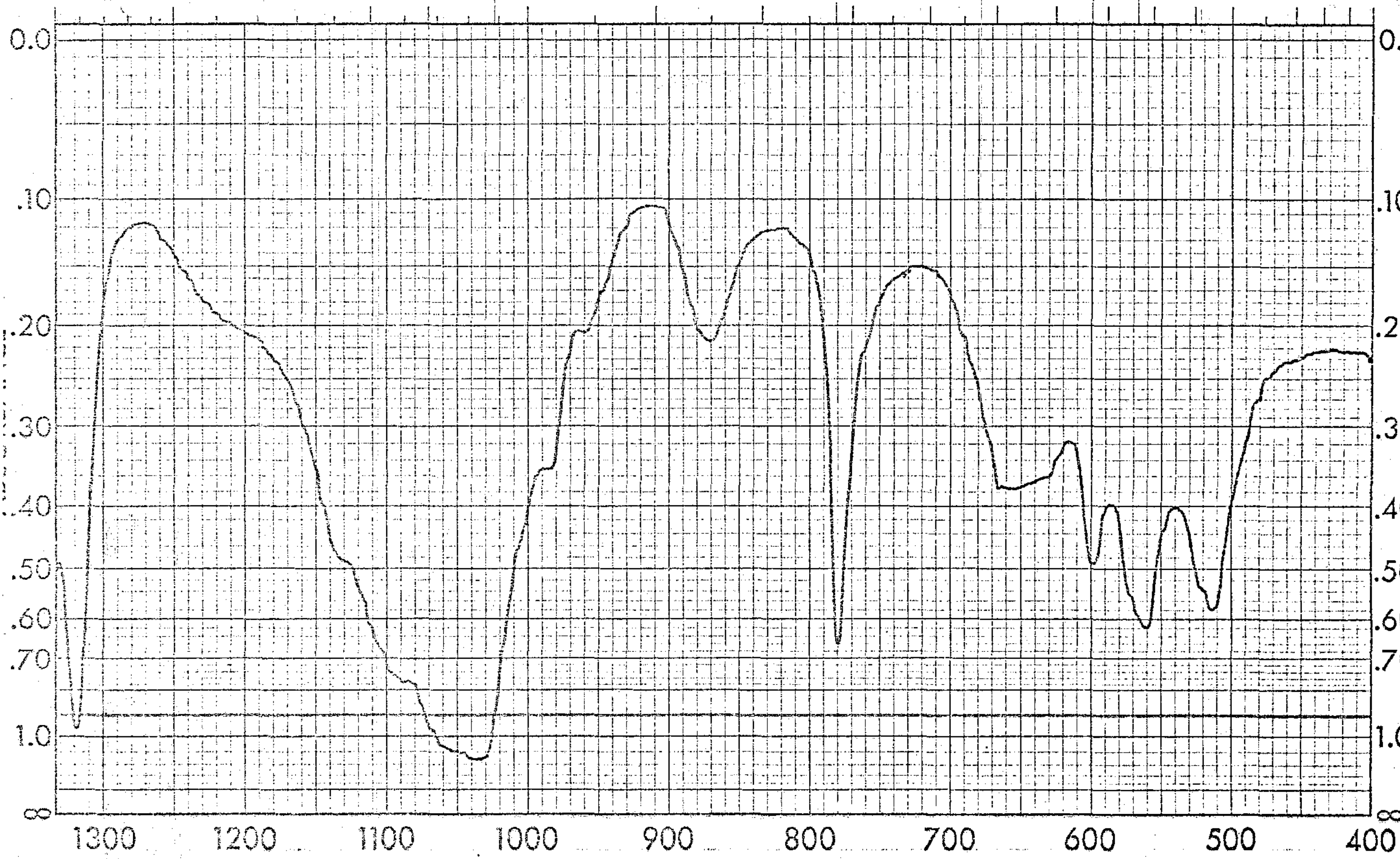


Spectrum No. 35: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.

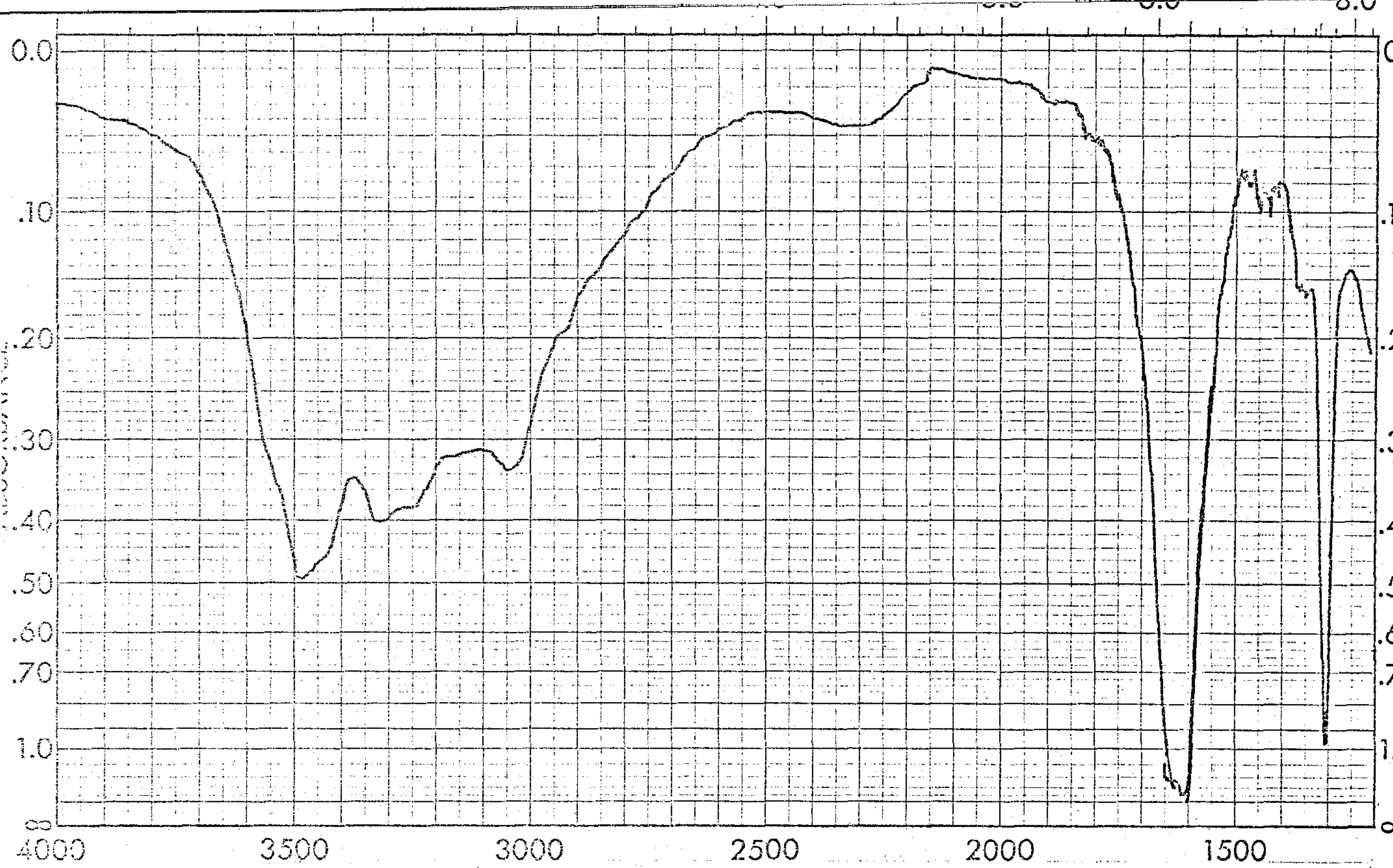


Spectrum No. 36: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.

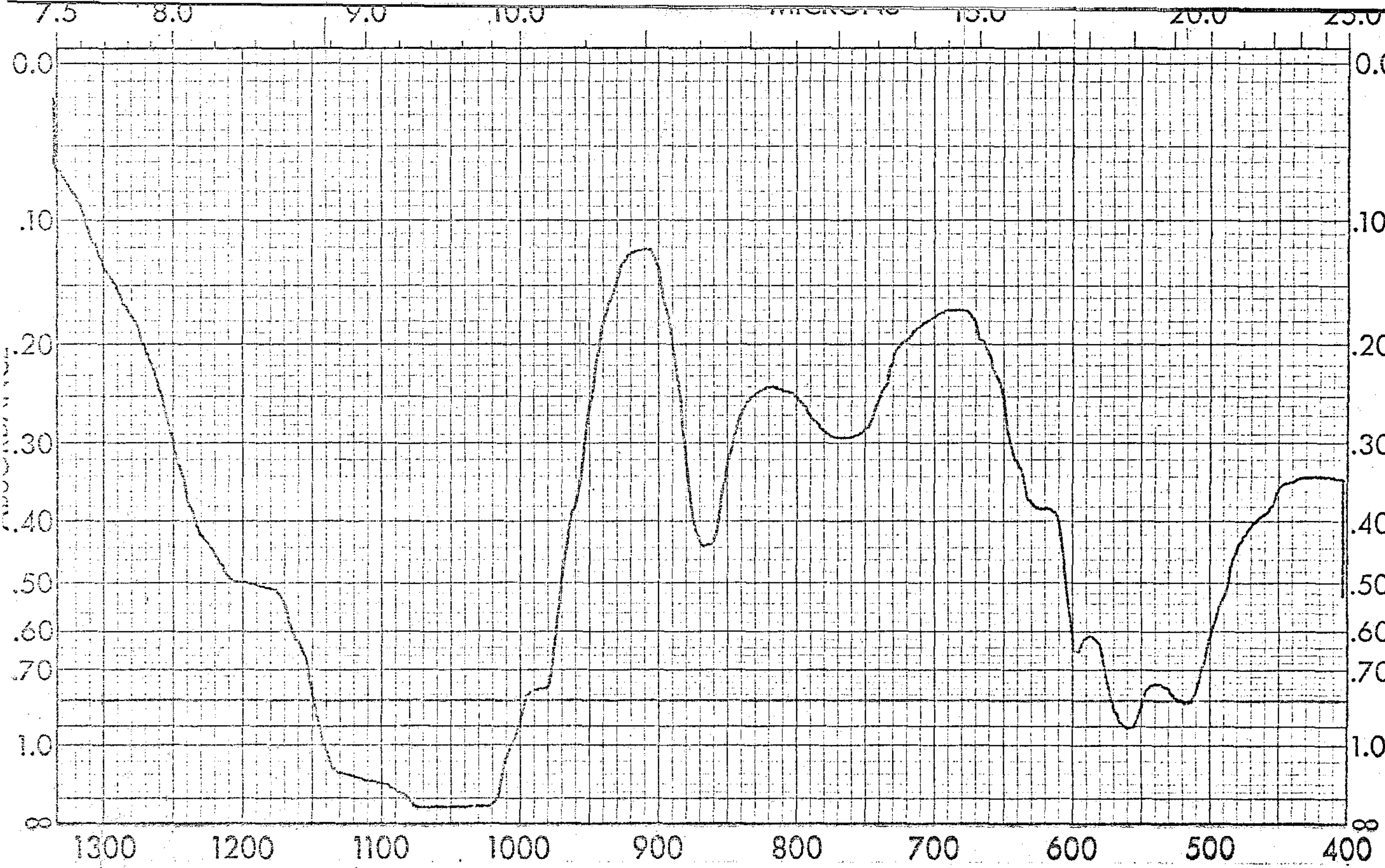
Spectrum No. 36: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Calcium Oxalate Monohydrate, $CaC_aO_4 \cdot H_2O$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



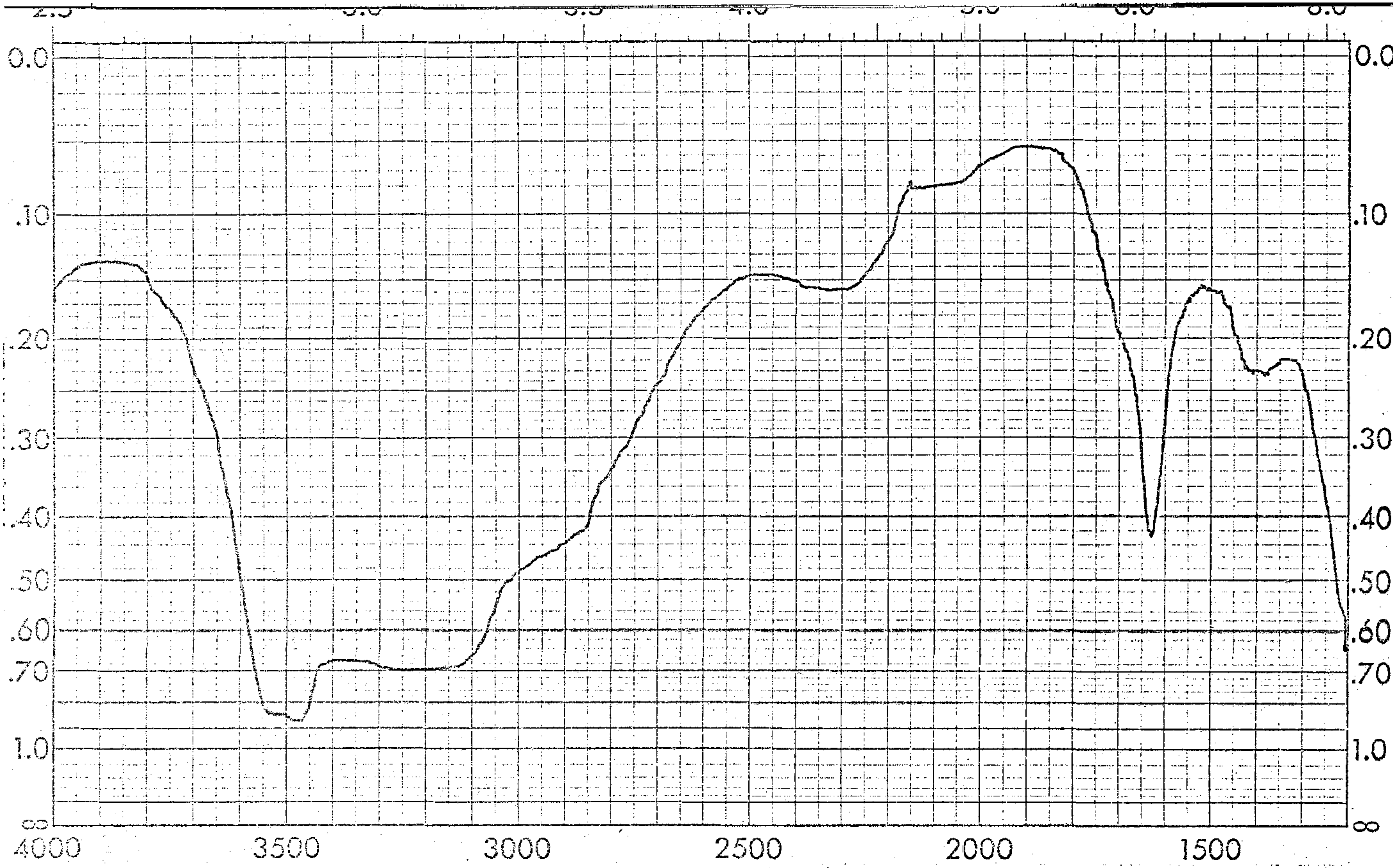
Spectrum No. 37: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$ By Transmission I.R.



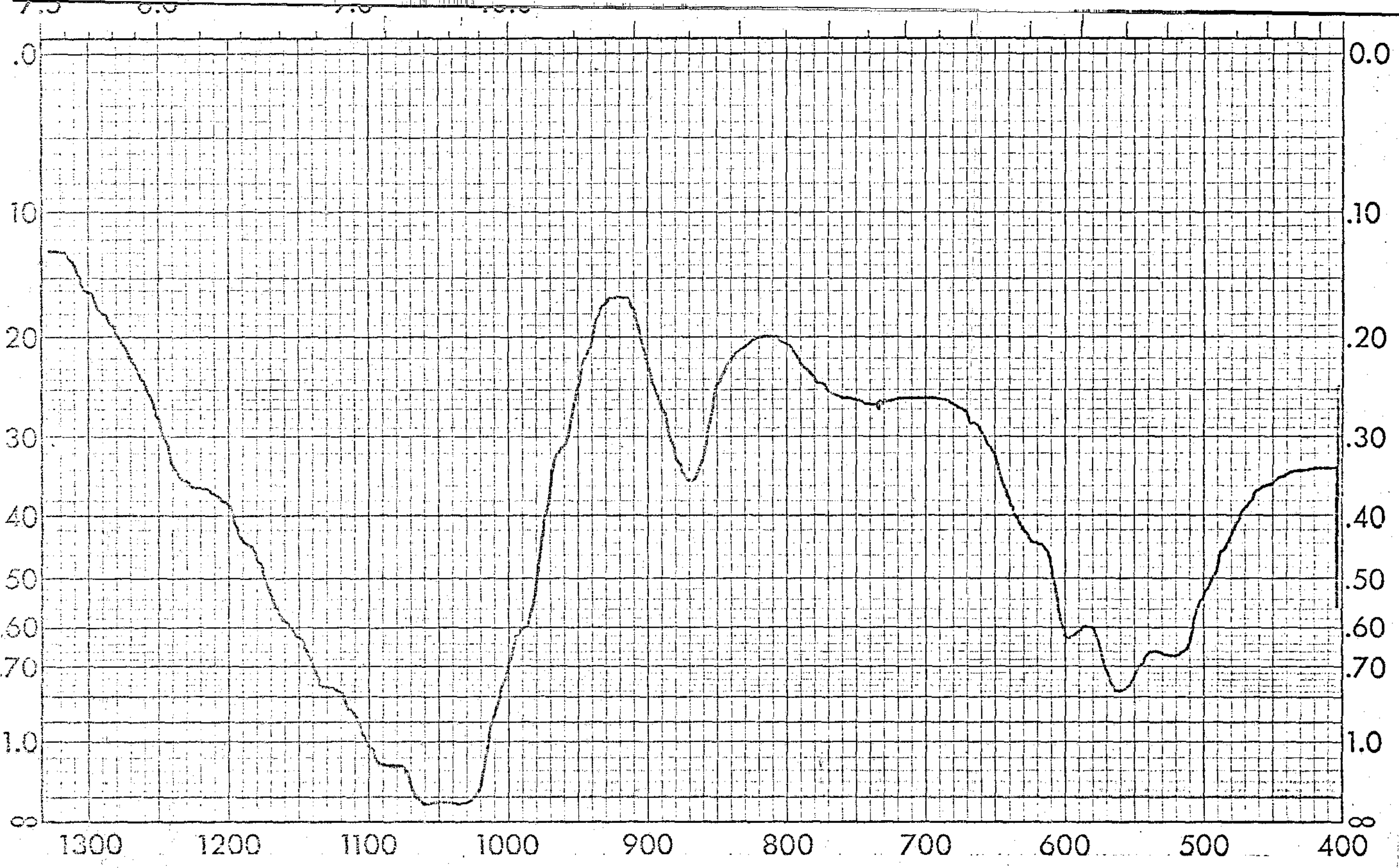
Spectrum No. 37: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$ By Transmission I.R.



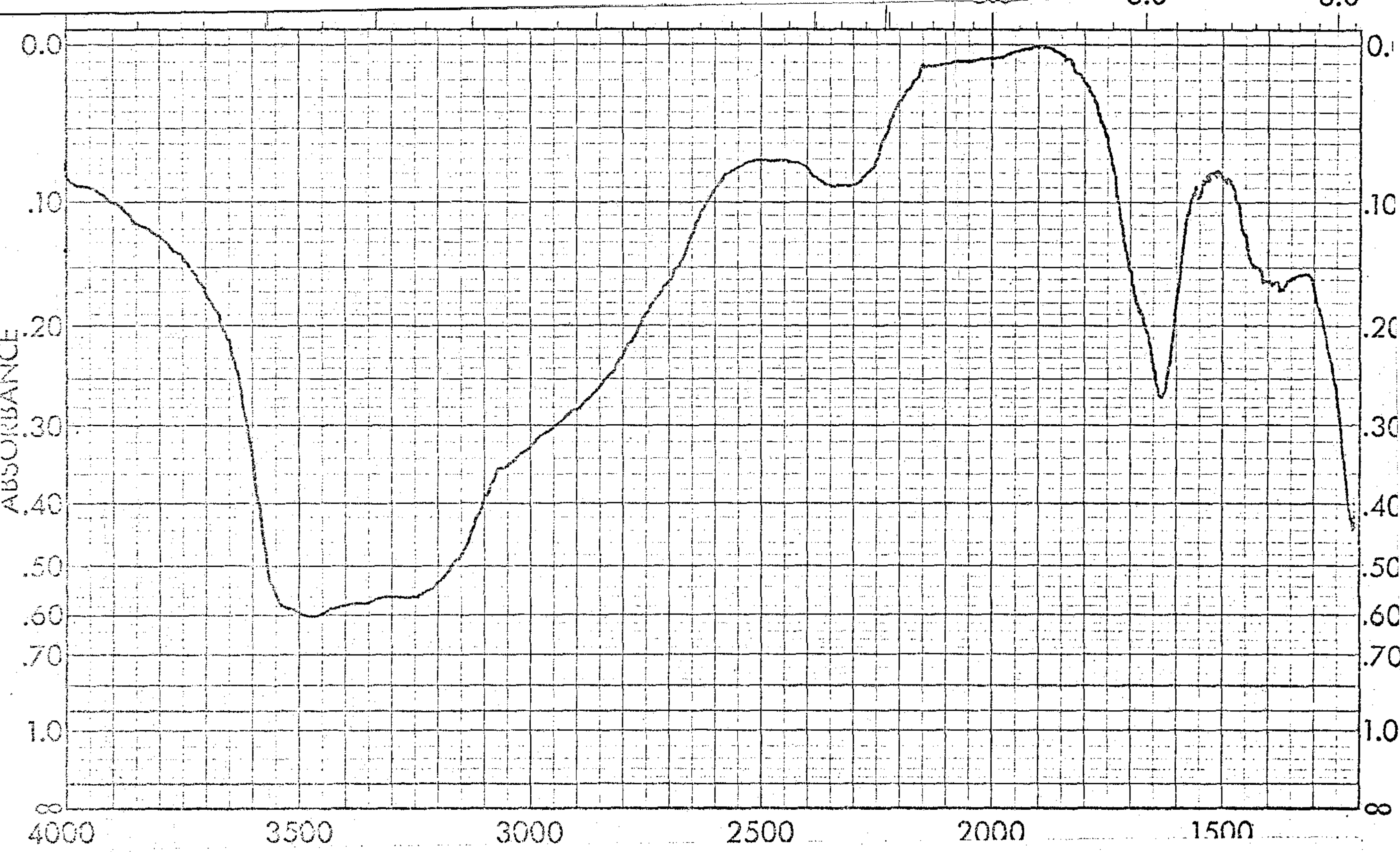
Spectrum No. 38: 50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ By Transmission I.R.



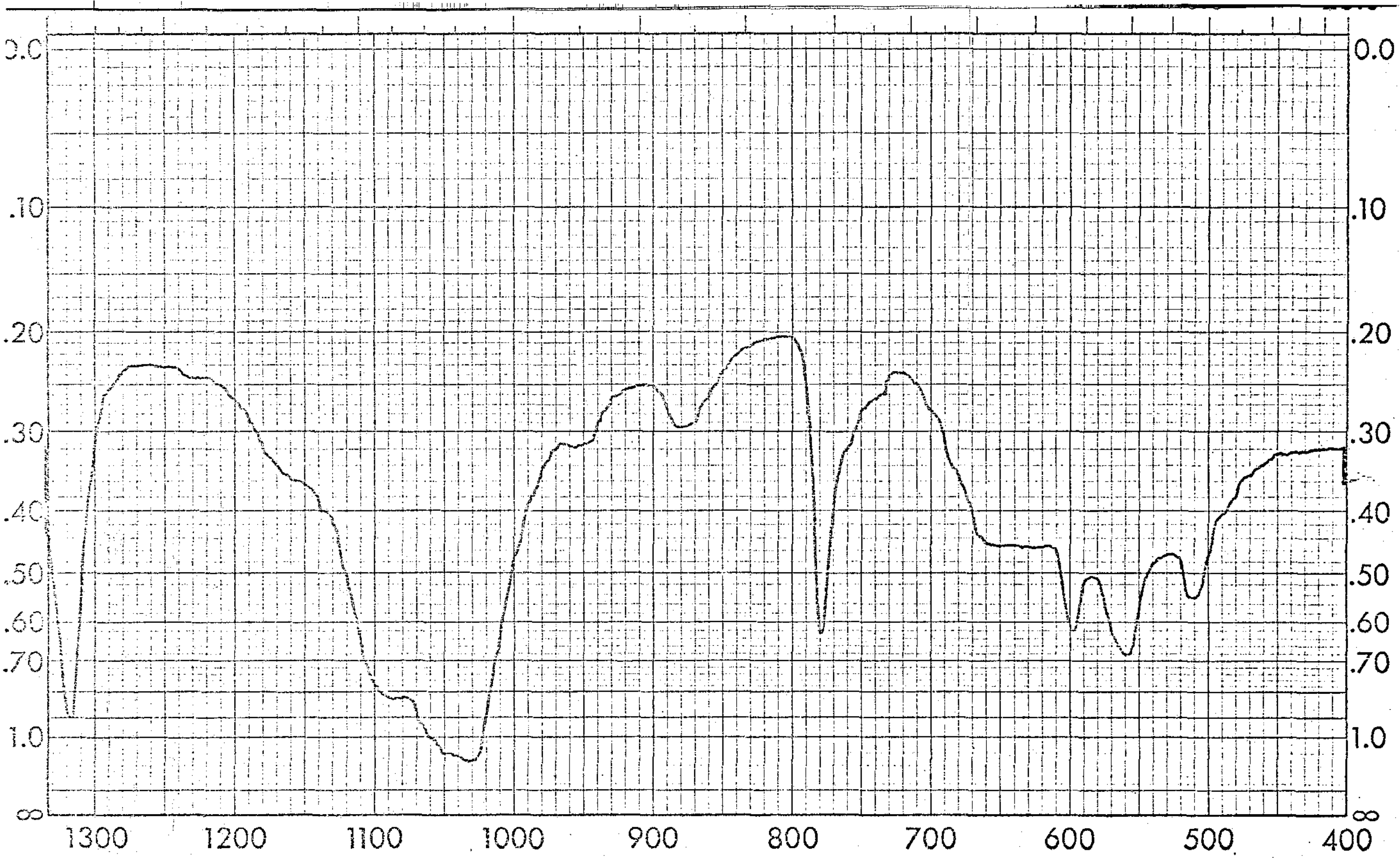
Spectrum No. 38: 50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ By Transmission I.R.



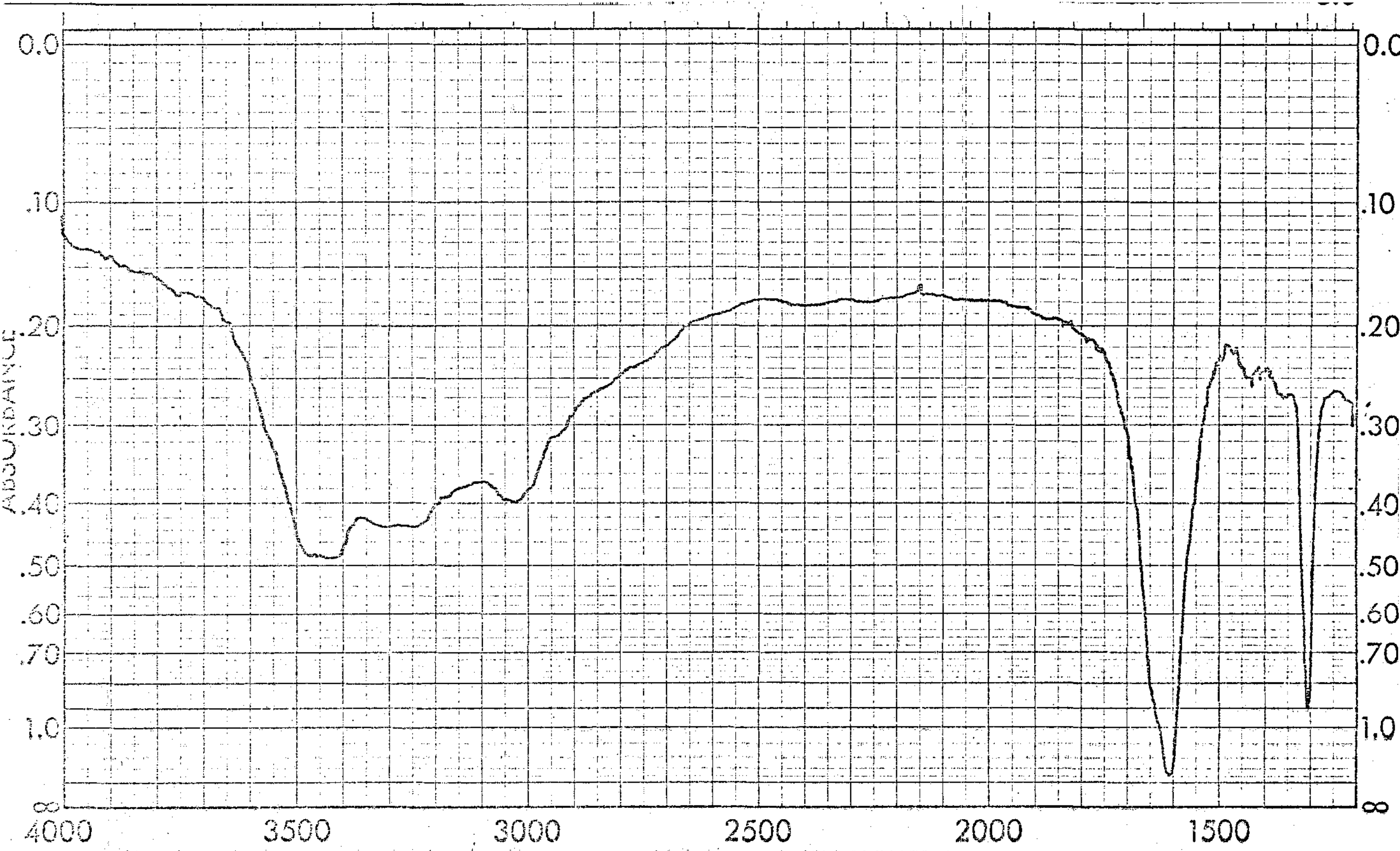
Spectrum No. 39: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



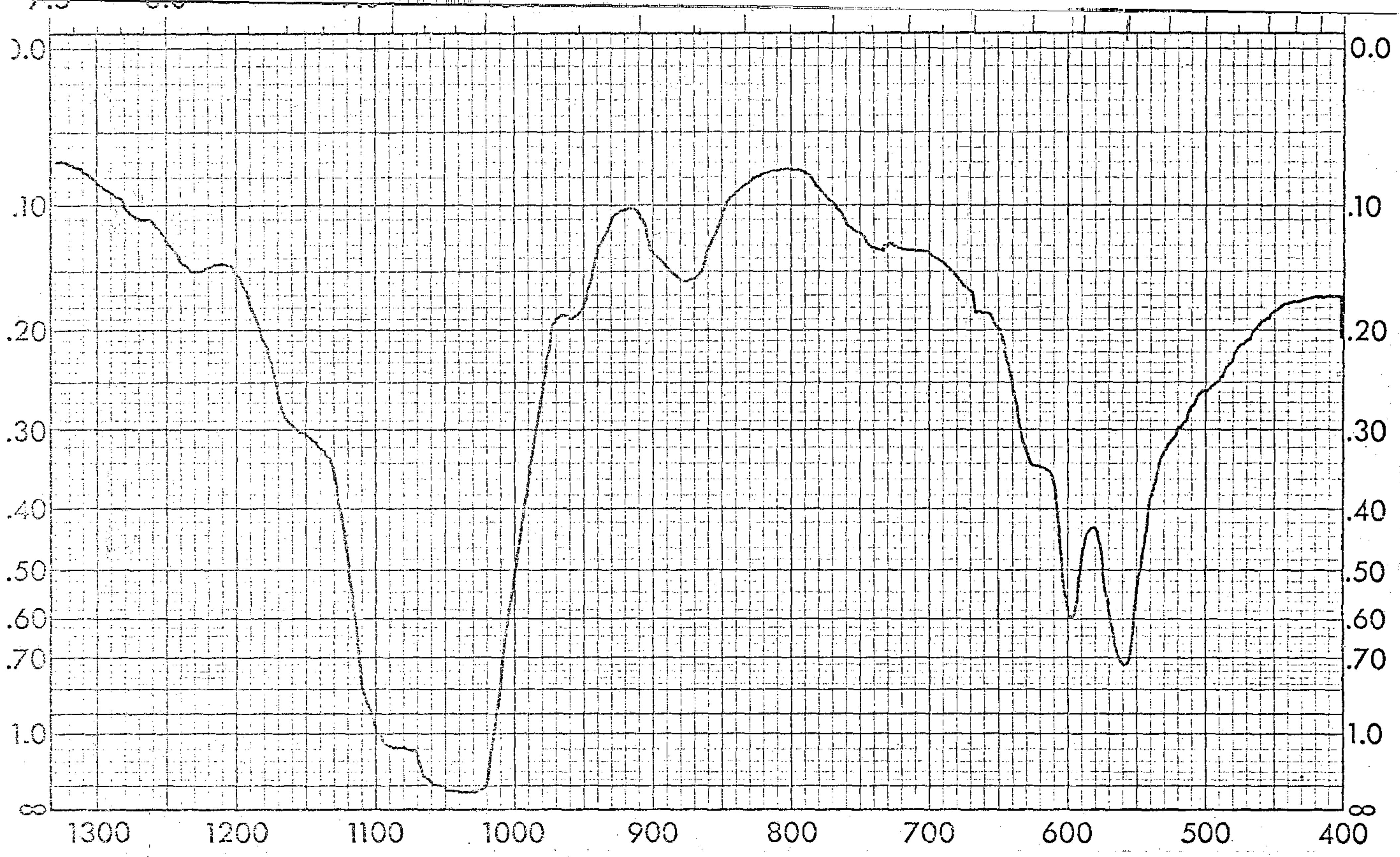
Spectrum No. 39: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



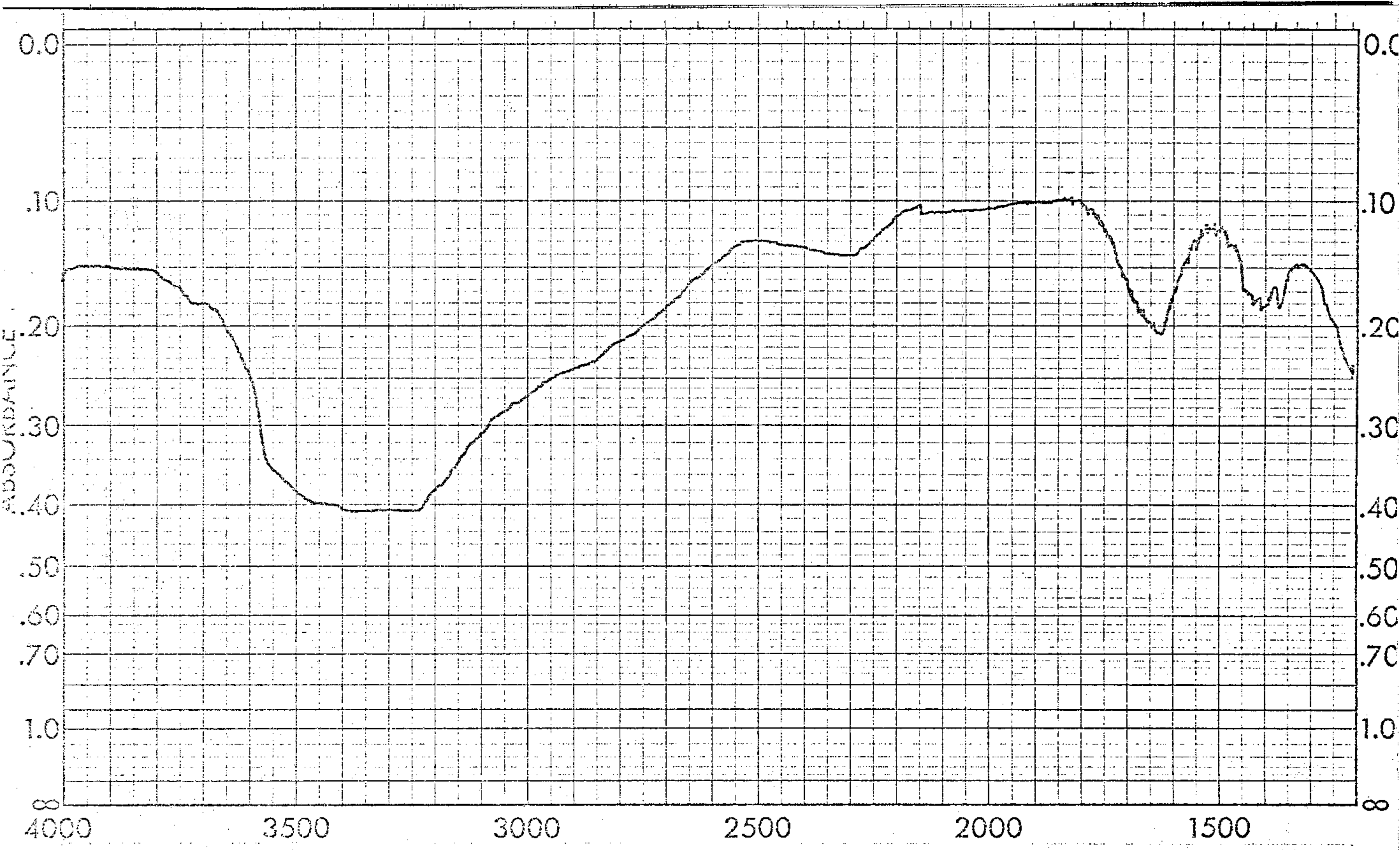
Spectrum No. 40: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ By Transmission I.R.



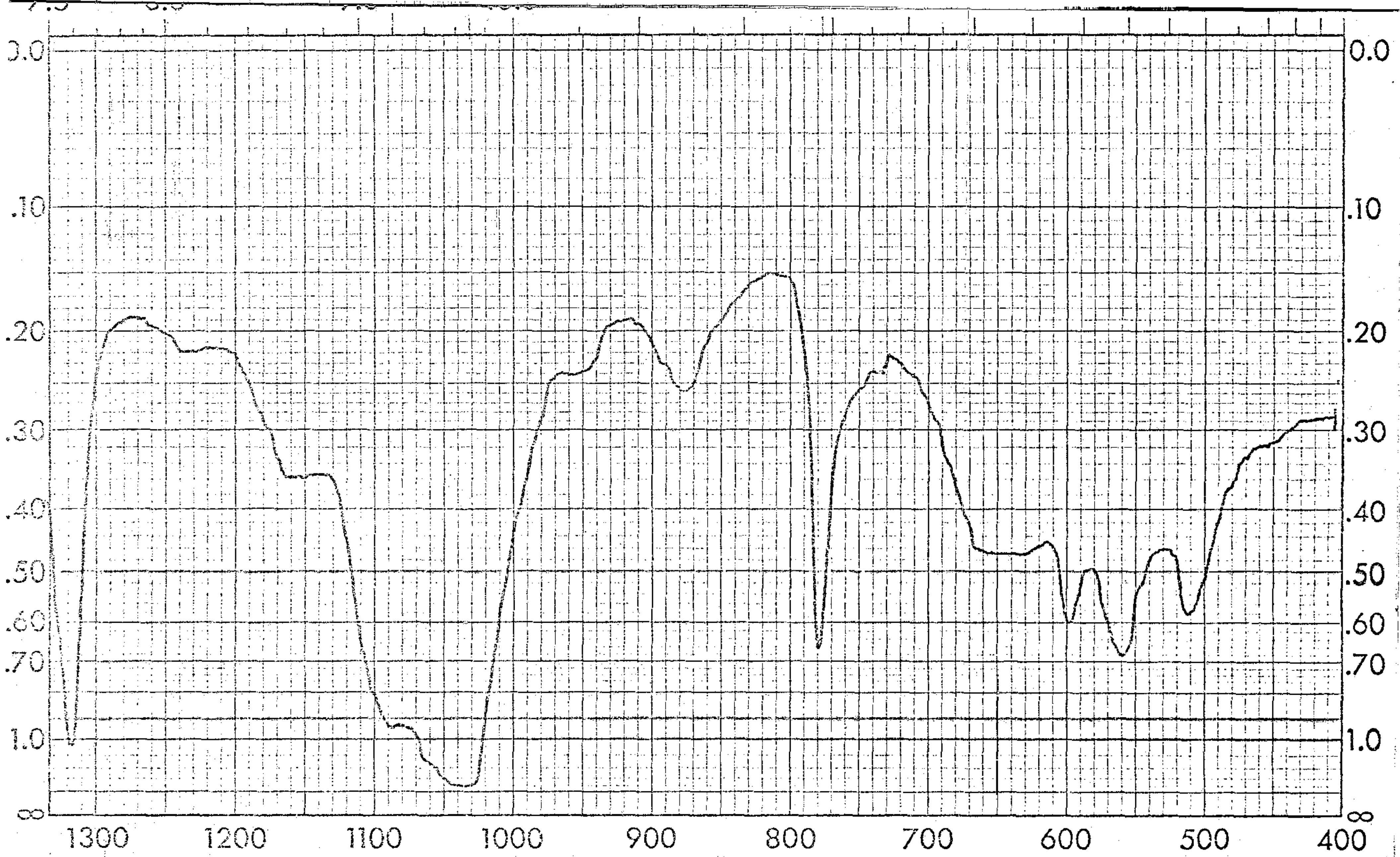
Spectrum No. 40: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$ By Transmission I.R.



Spectrum No. 41: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.

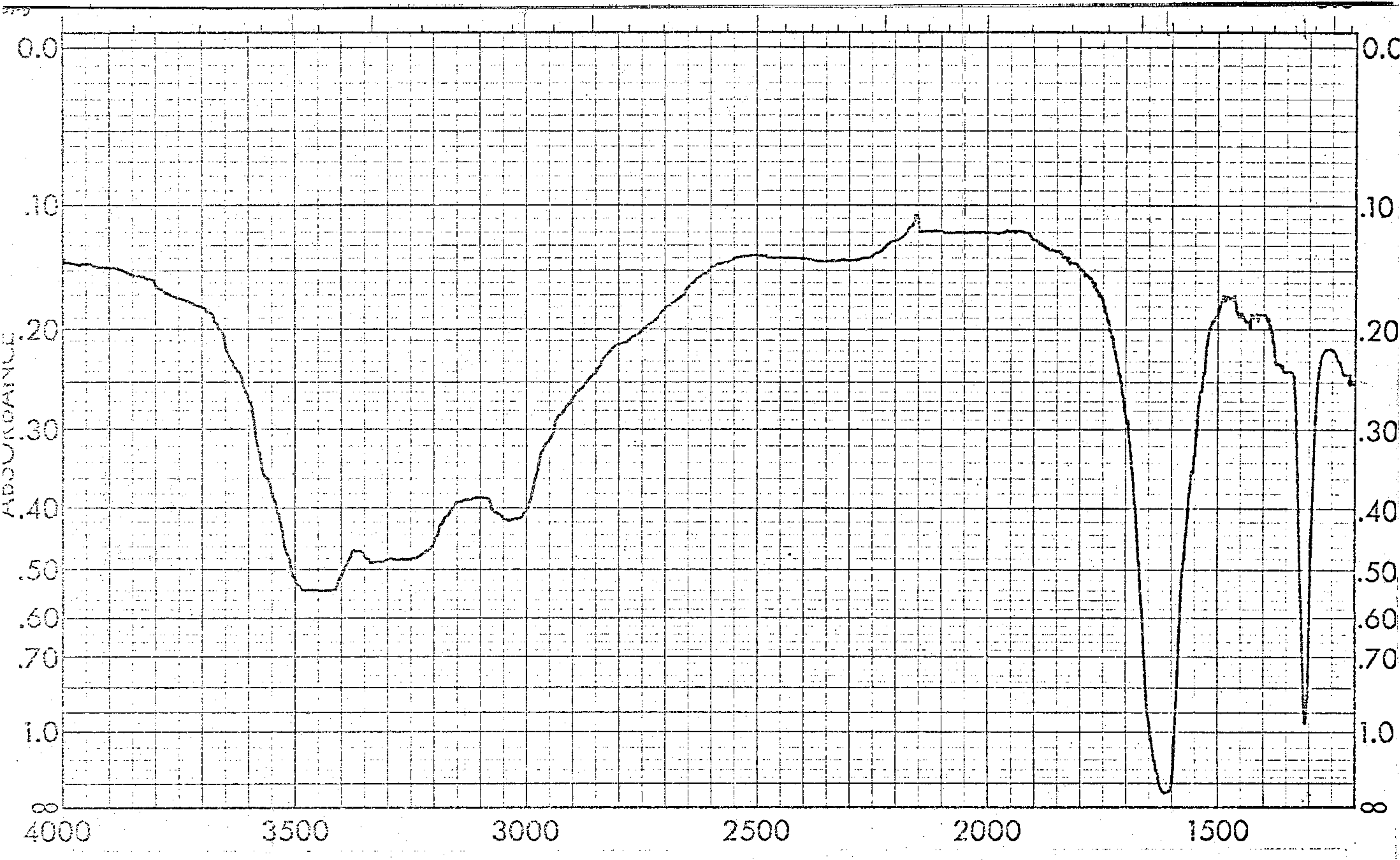


Spectrum No. 41: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.

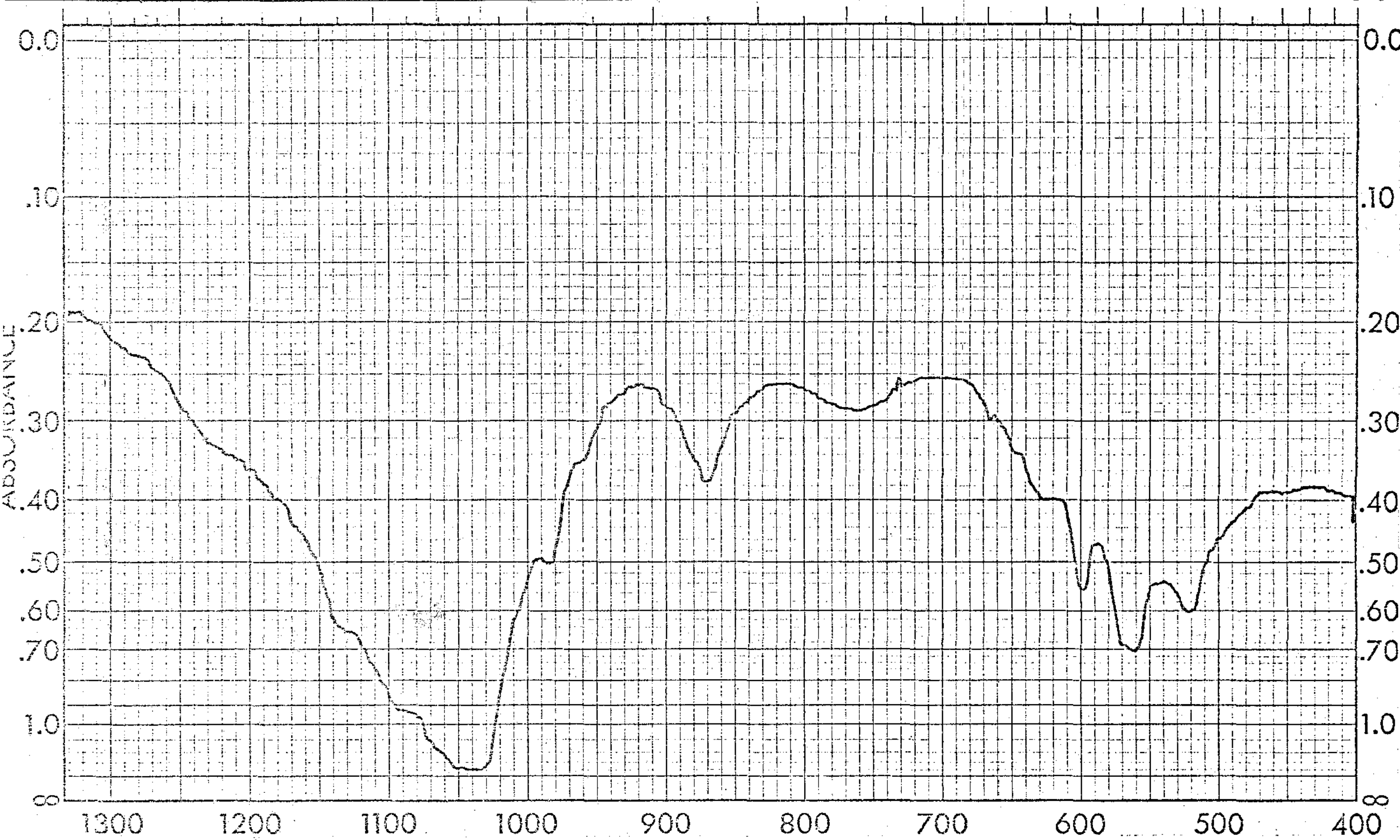


Spectrum No. 42: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, and 25% Magnesium Phosphate, $MgHPO_4$

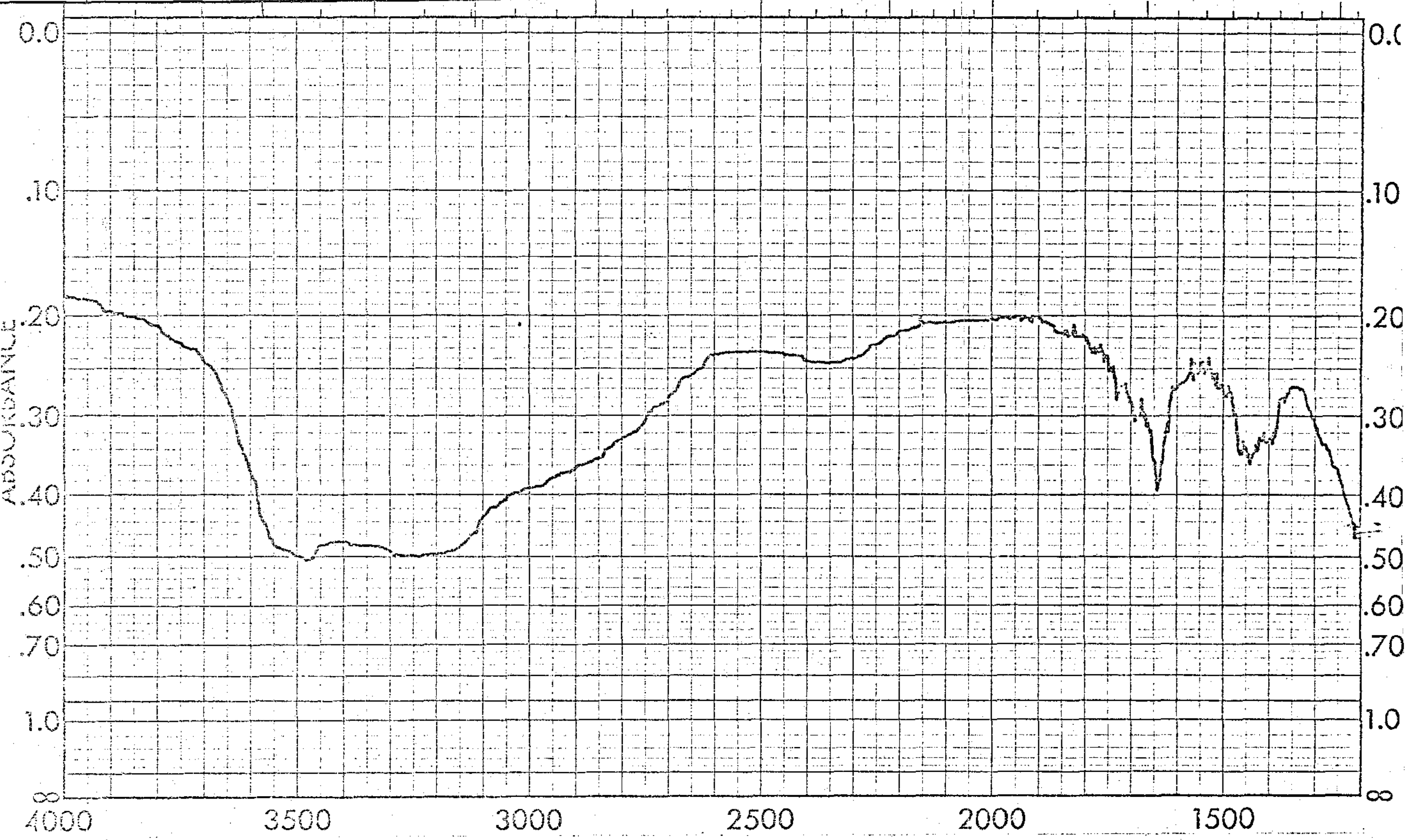
By Transmission I.R.



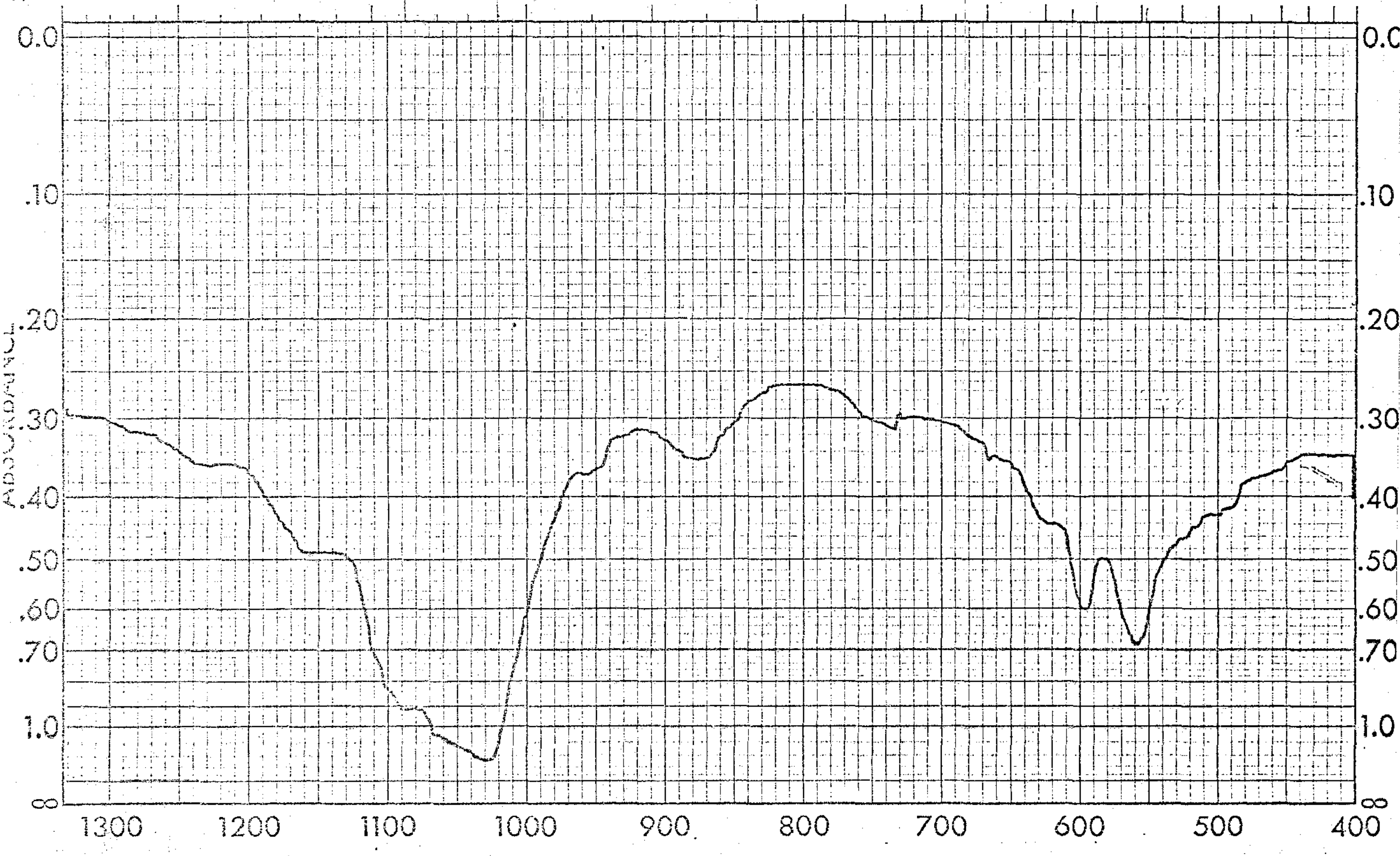
Spectrum No. 42: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



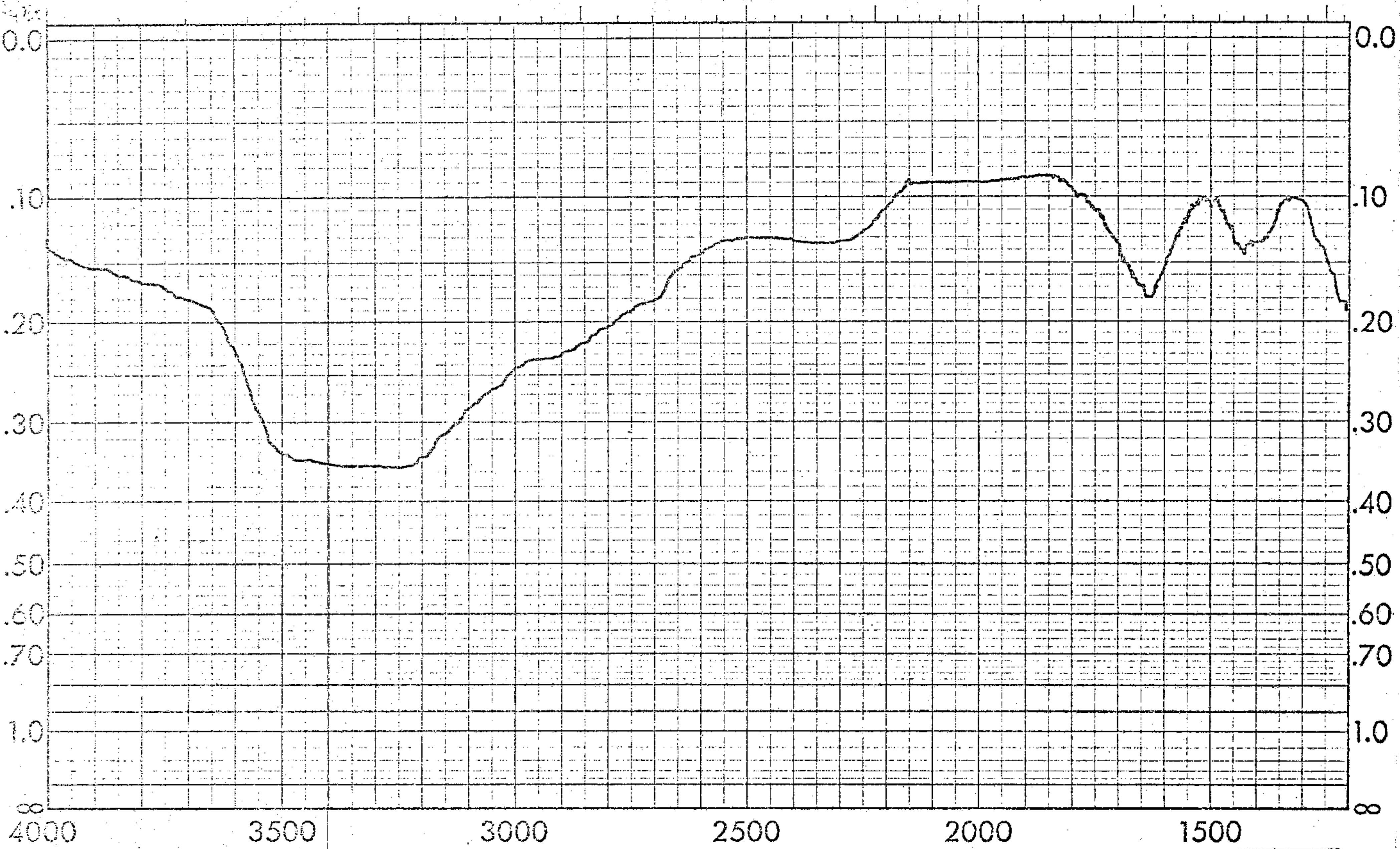
Spectrum No. 43: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.



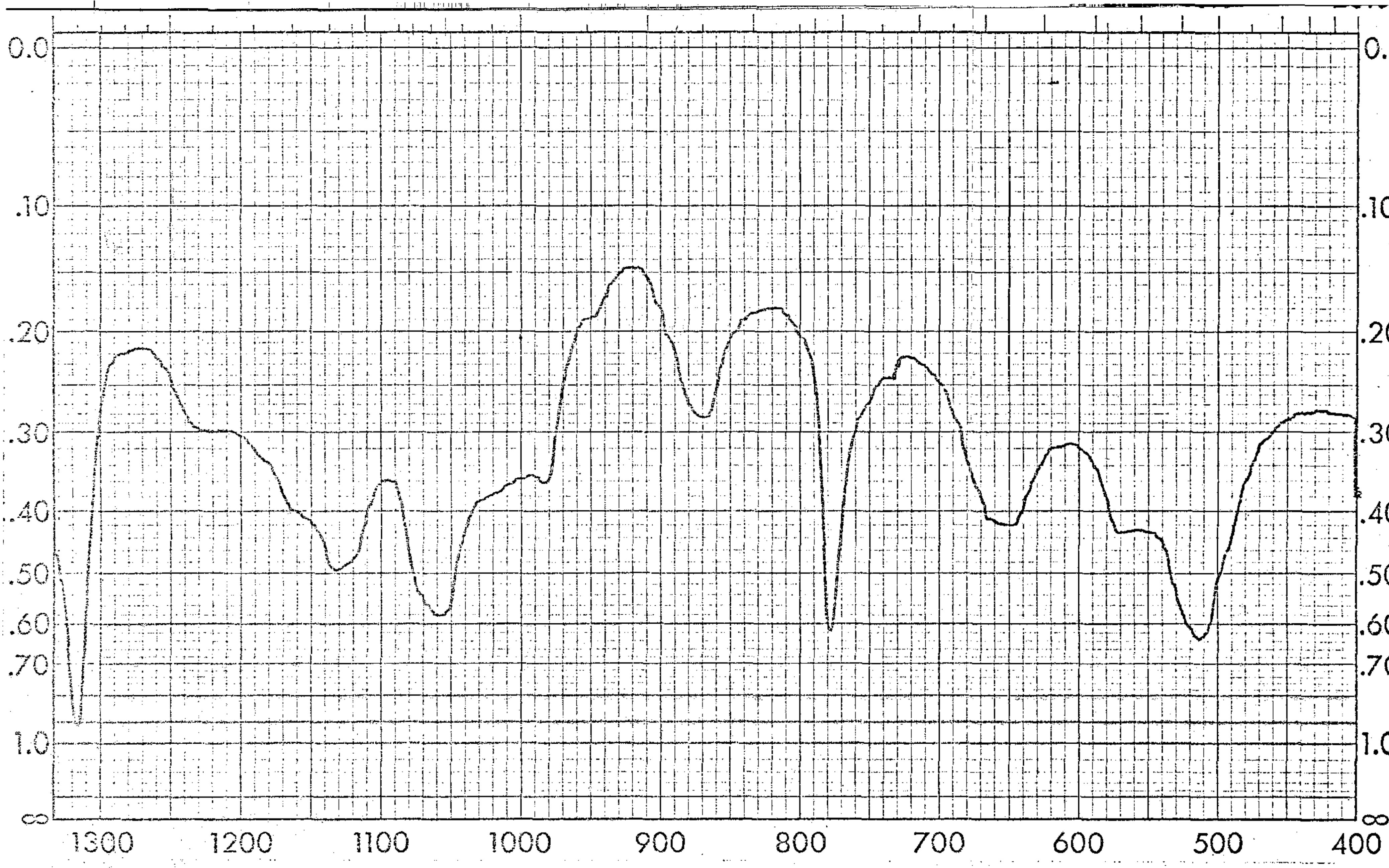
Spectrum No. 43: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.



Spectrum No. 44: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Magnesium Phosphate, $MgHPO_4$, and 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$ By Transmission I.R.

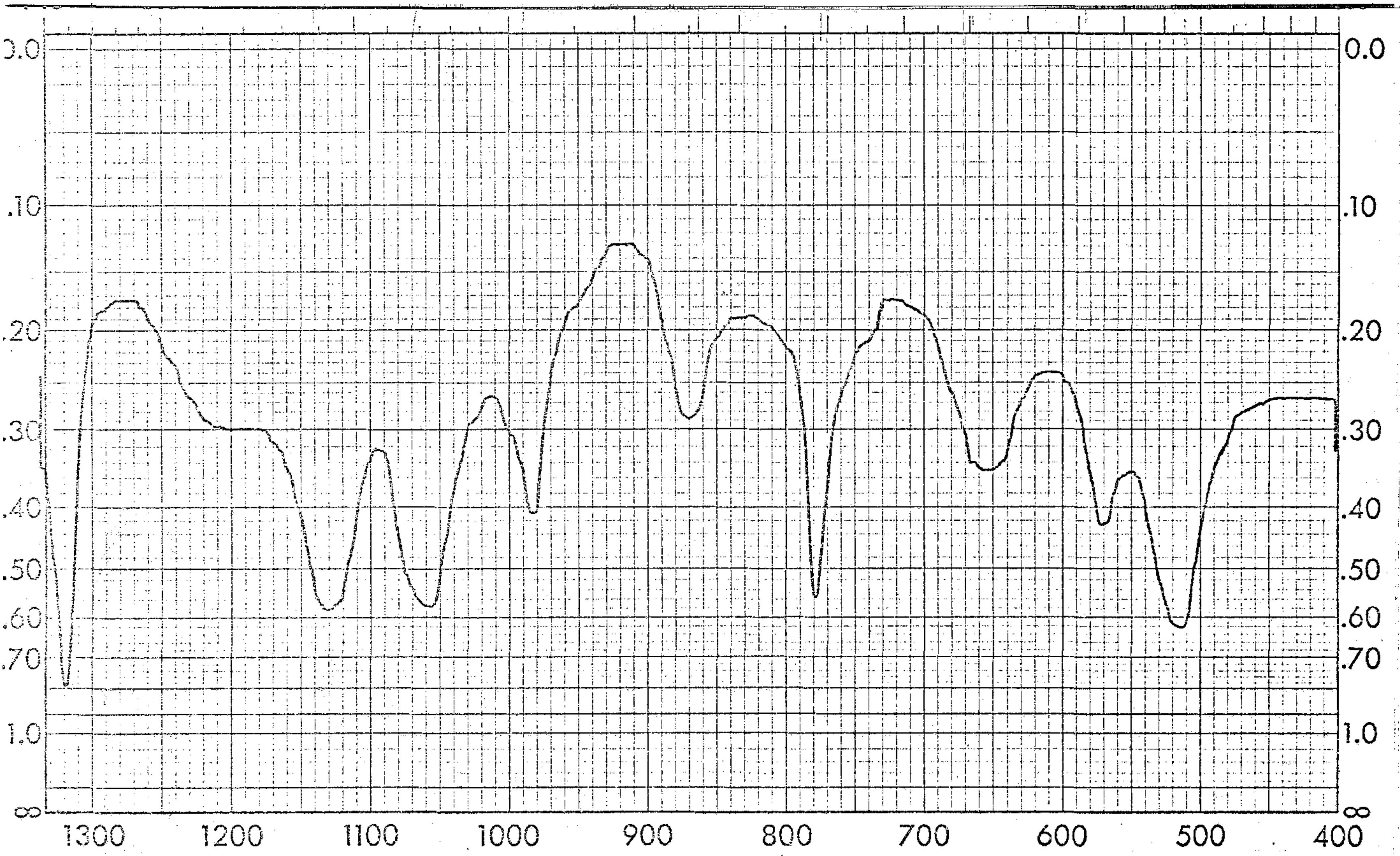


Spectrum No. 44: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Magnesium Phosphate, $MgHPO_4$, and 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$ By Transmission I.R.



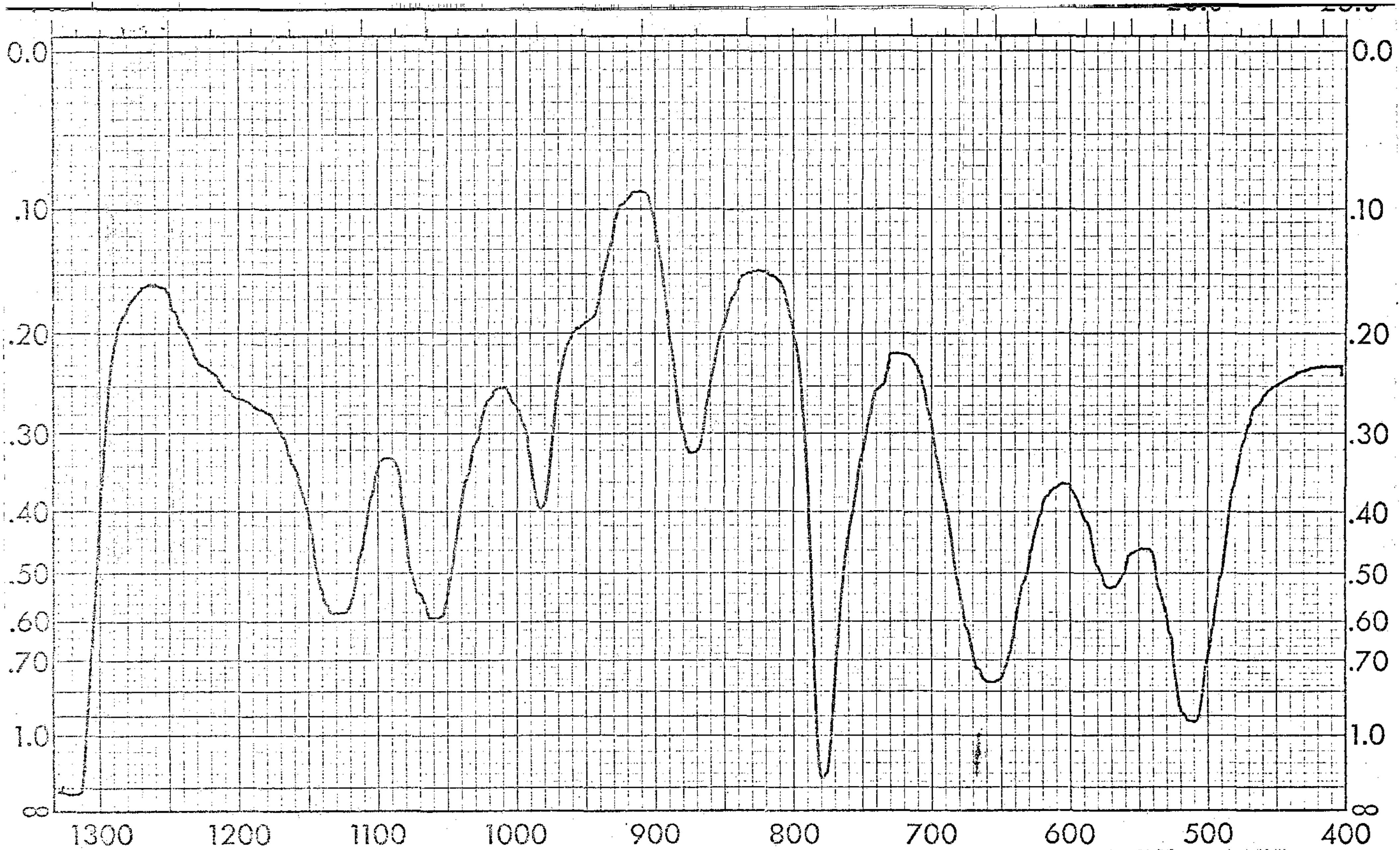
Spectrum No. 45: 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate, $MgHPO_4$. By Transmission I.R.

Spectrum No. 45: 25% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.

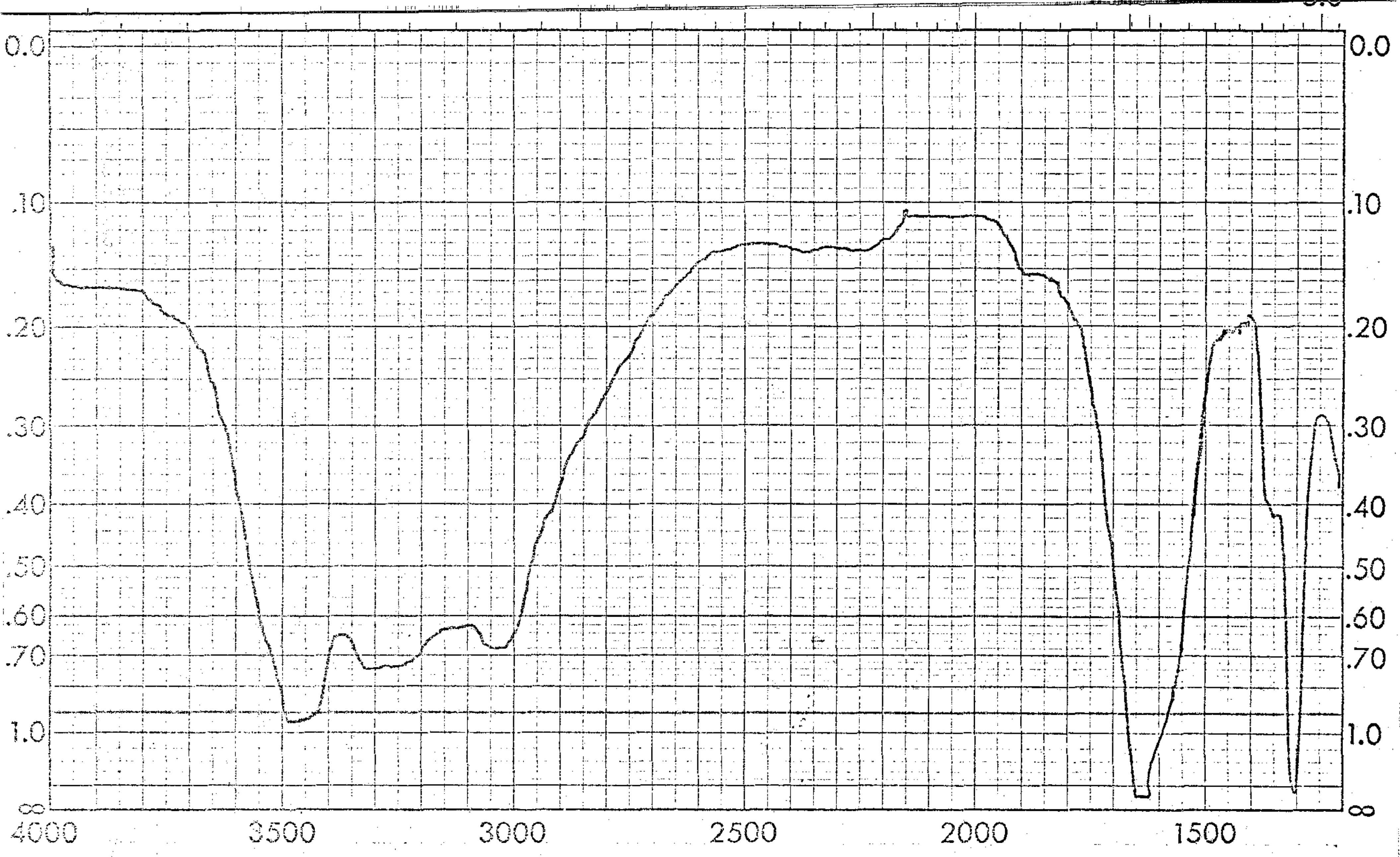


Spectrum No. 46: 50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ By Transmission I.R.

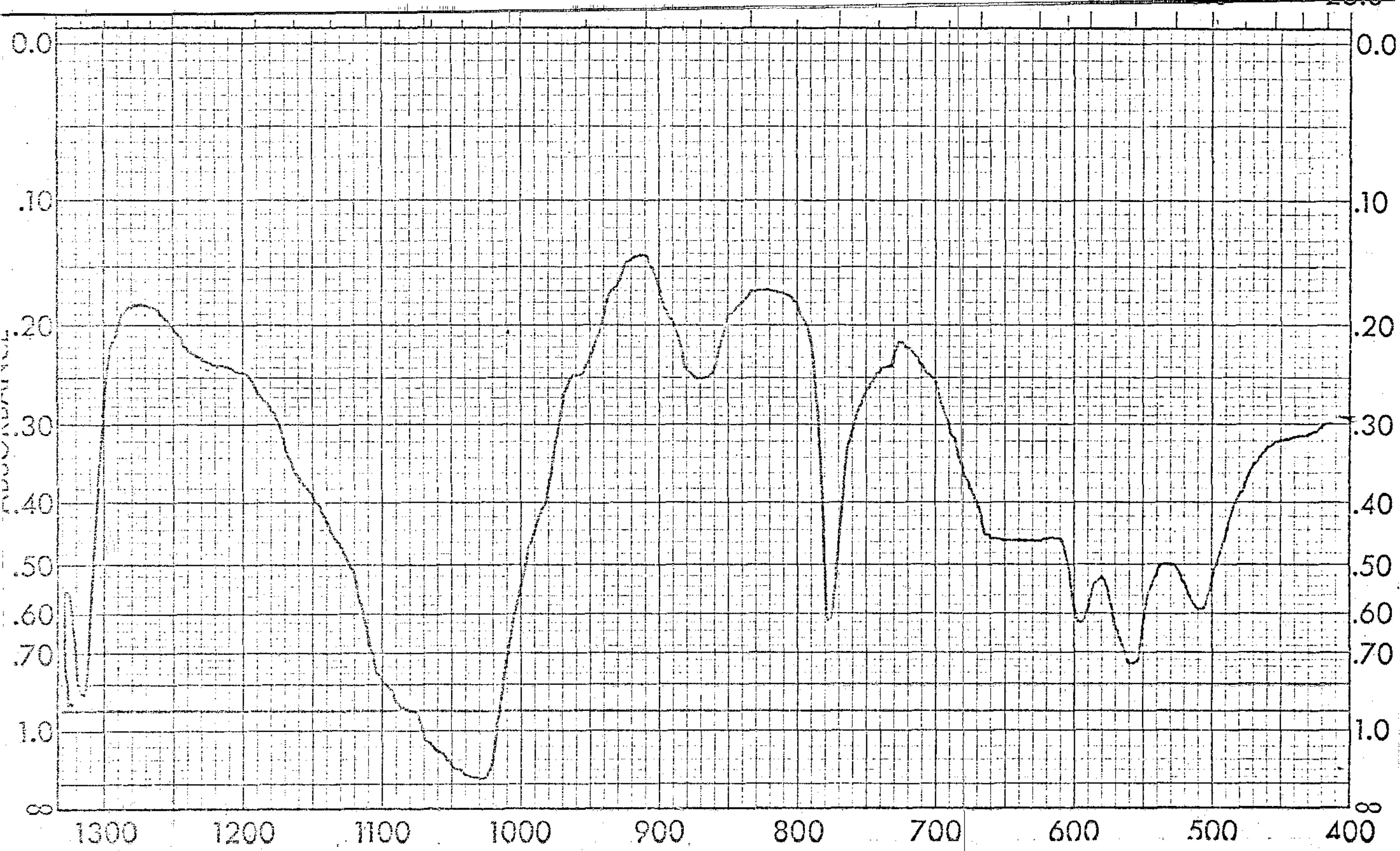
Spectrum No. 46: 50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ By Transmission I.R.



Spectrum No. 47: 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, and 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ By Transmission I.R.

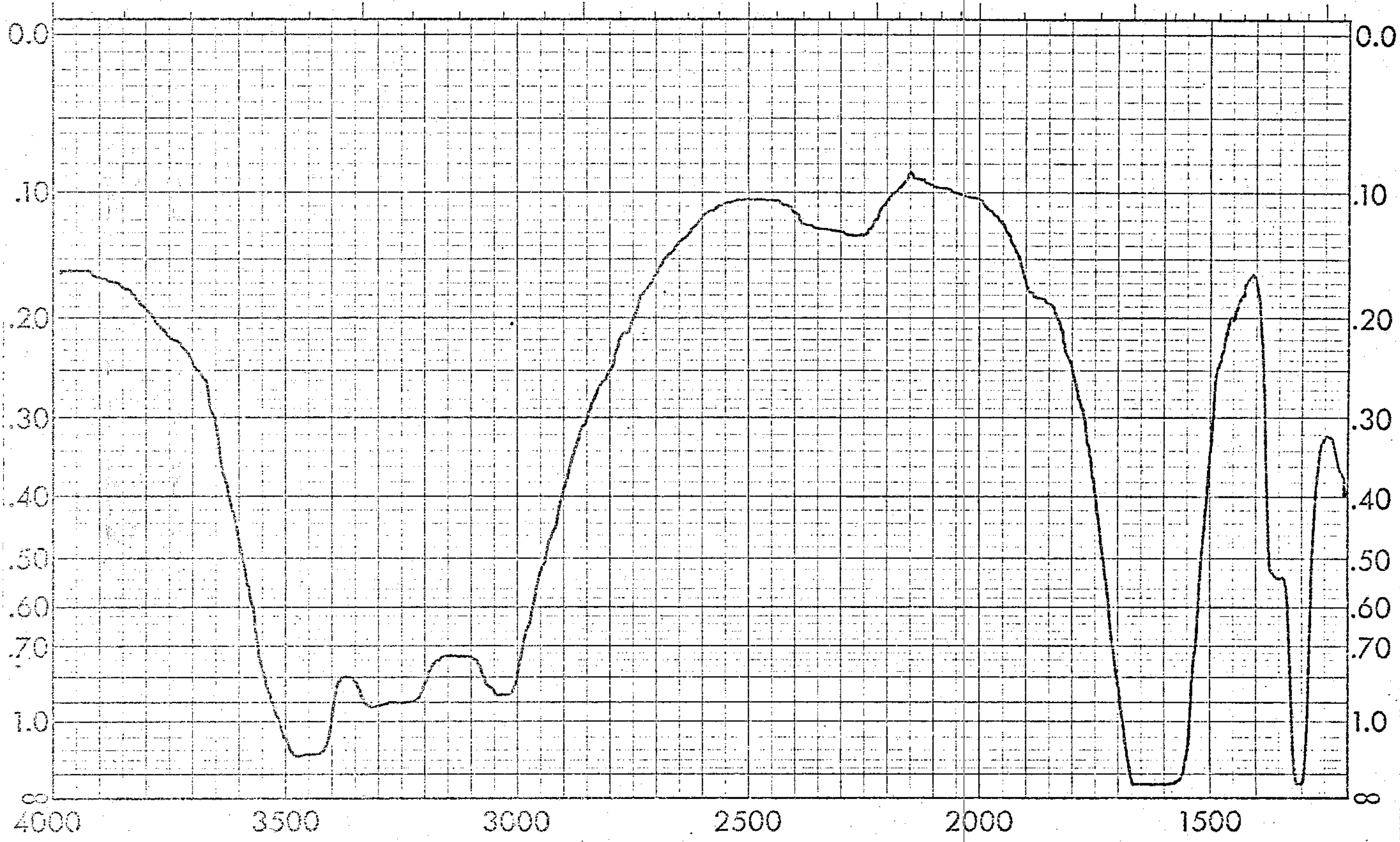


Spectrum No. 47: 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, and 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ By Transmission I.R.

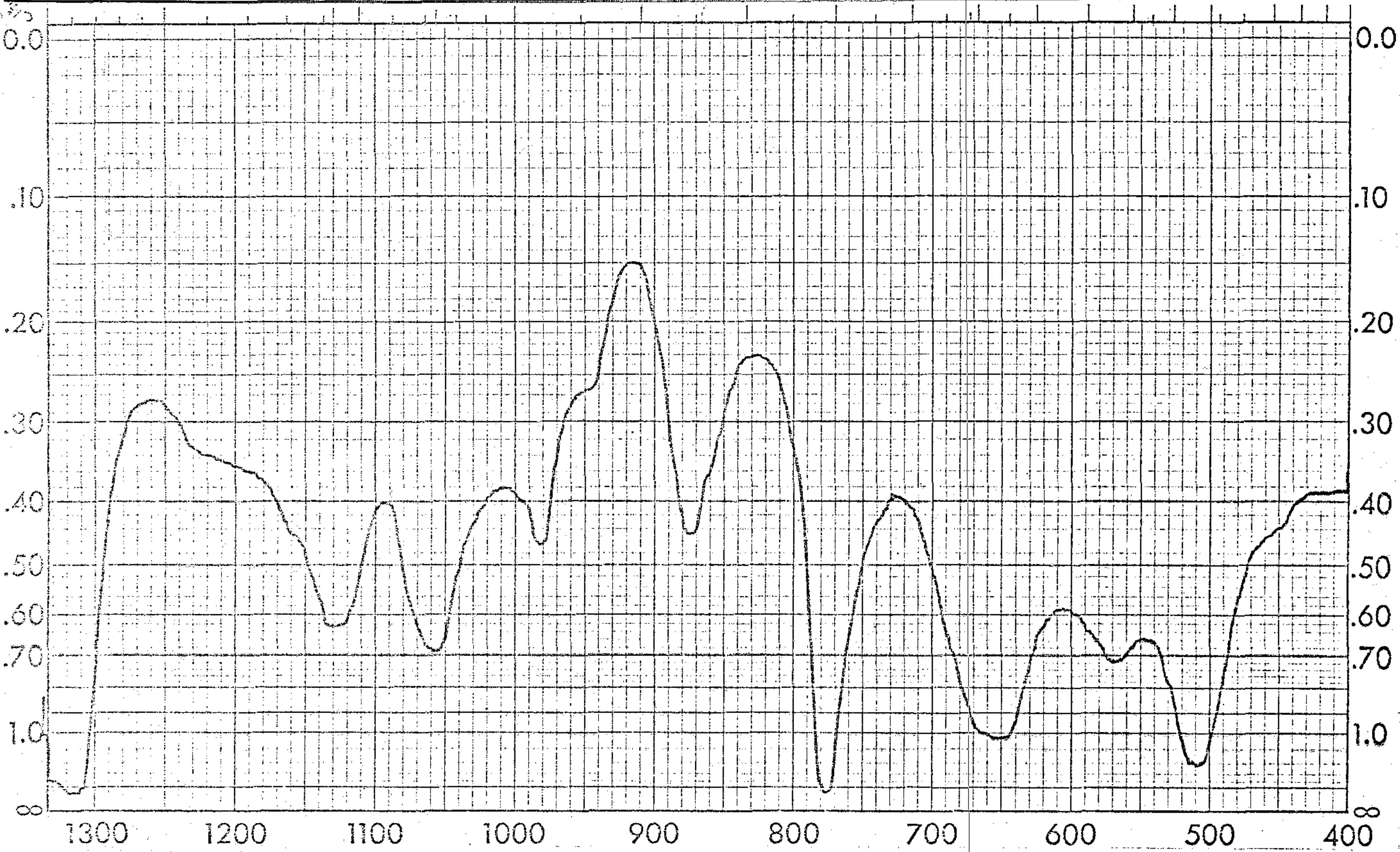


Spectrum No. 48: 25% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.

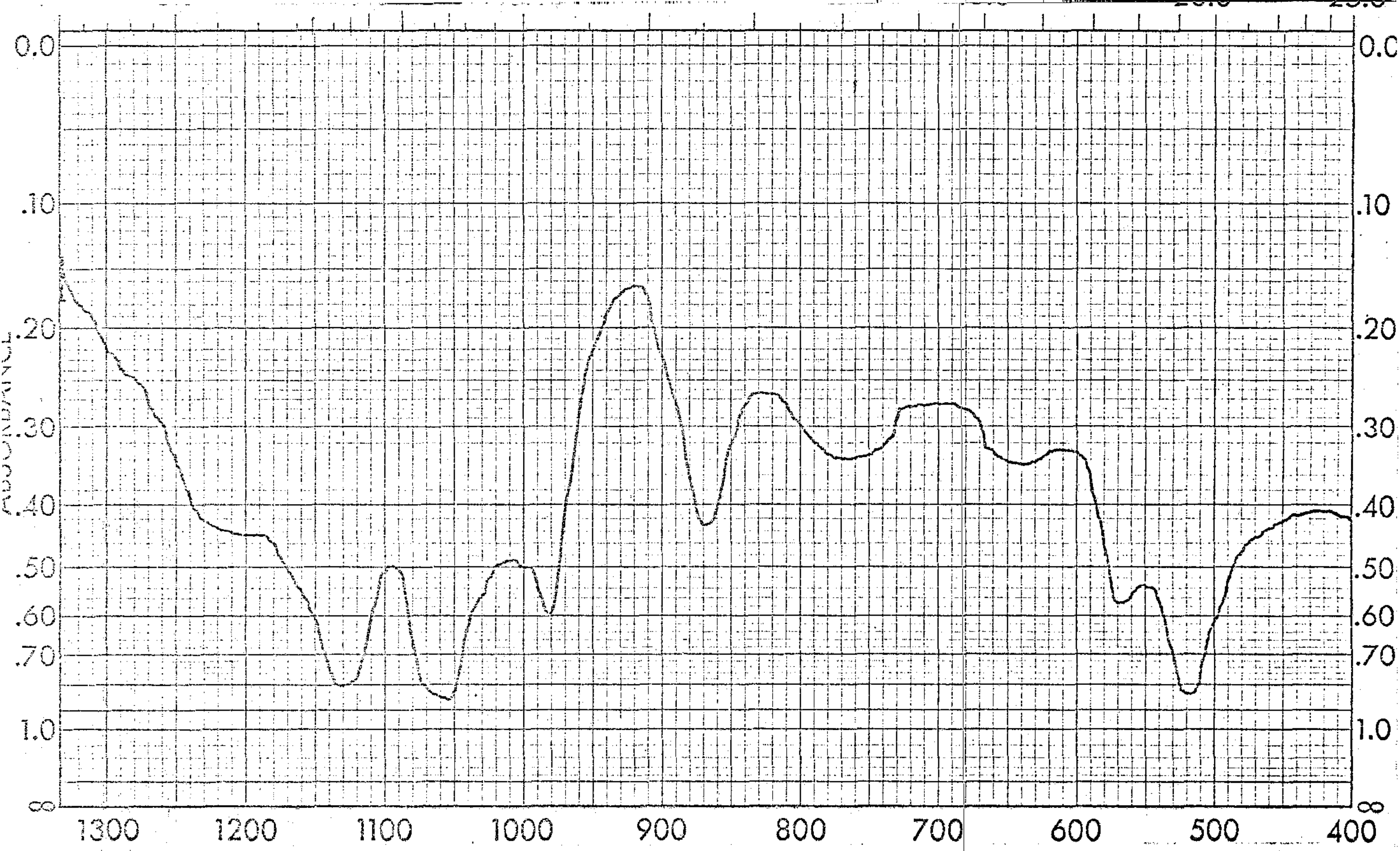
Spectrum No. 48: 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



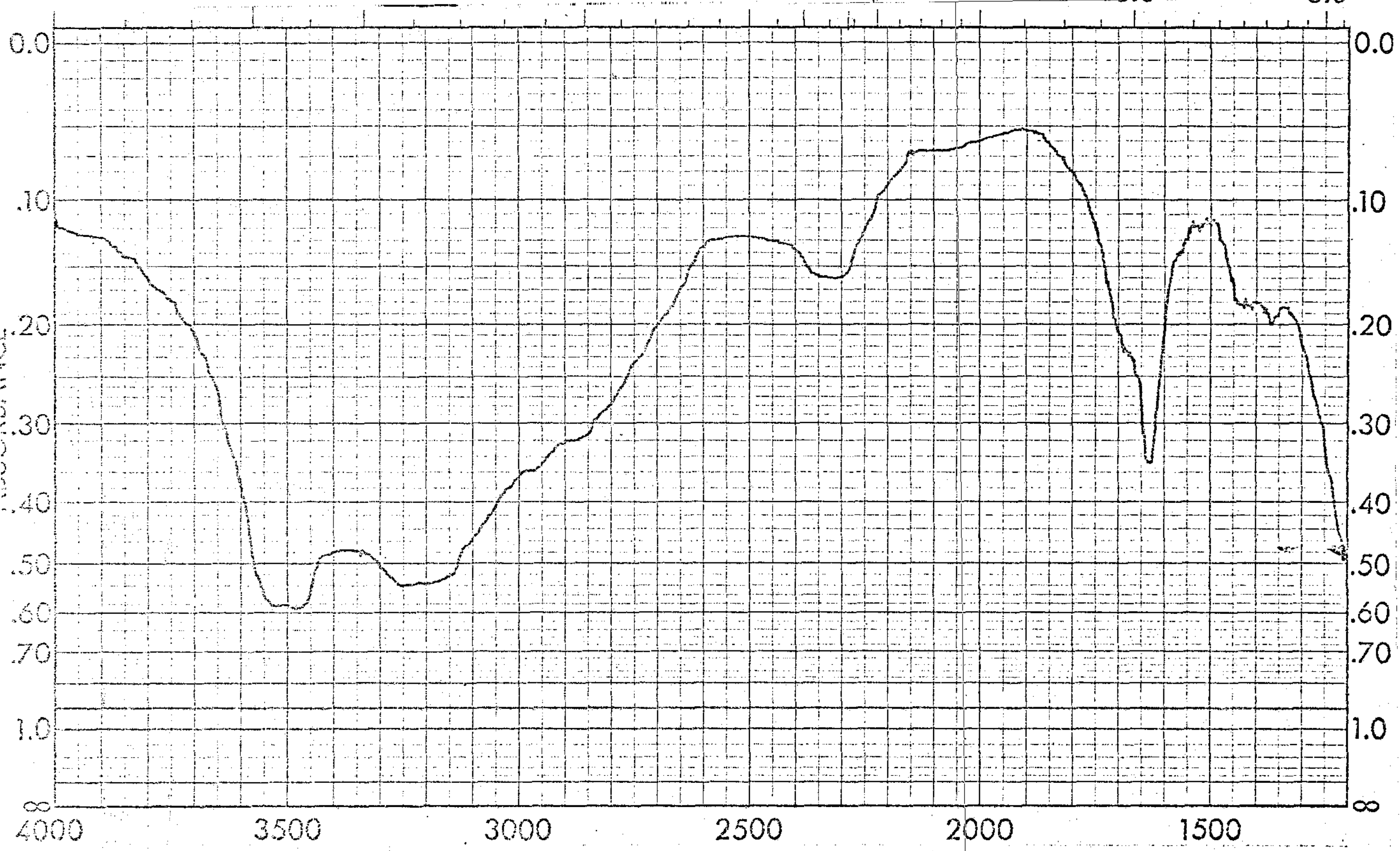
Spectrum No. 49: 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



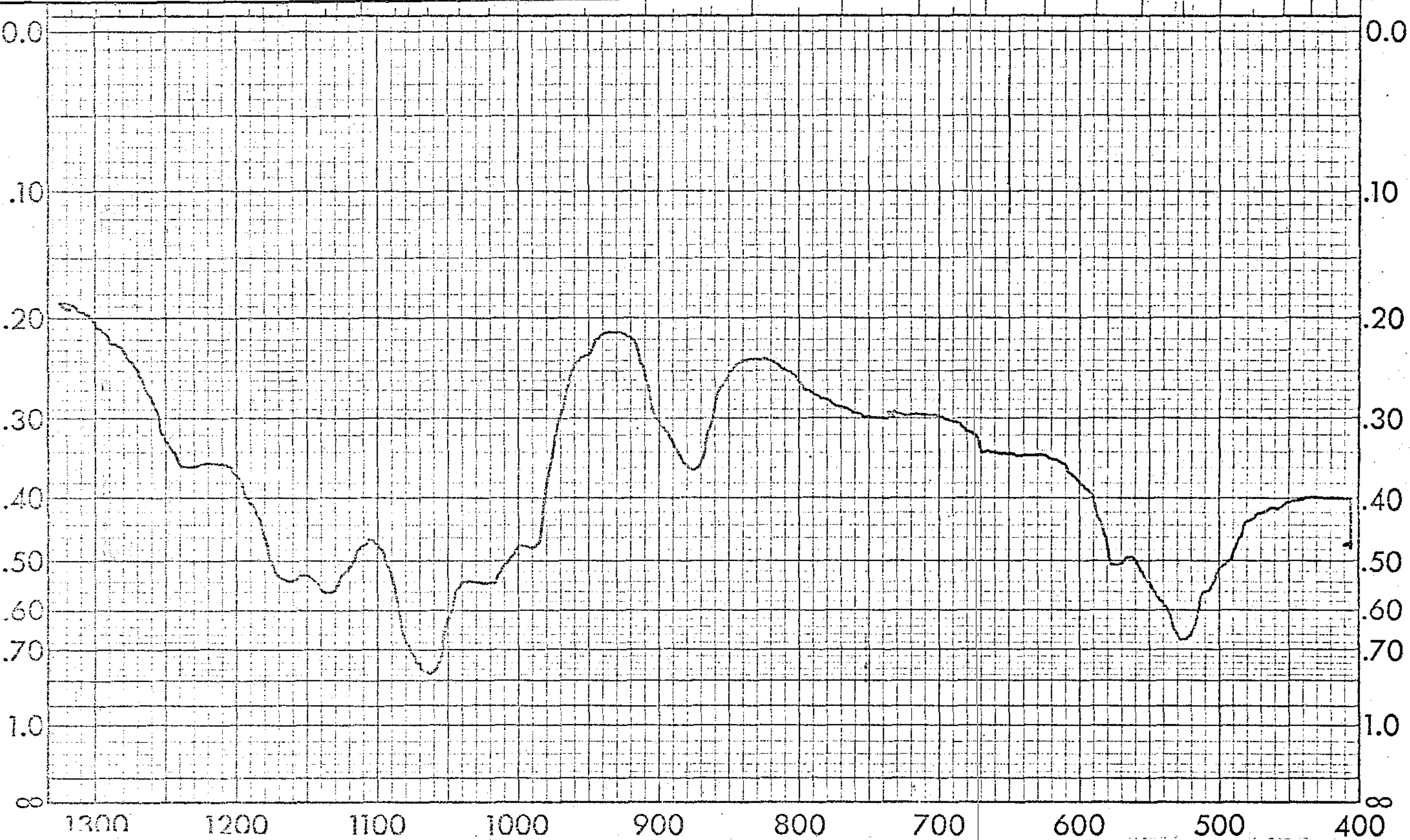
Spectrum No. 49: 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



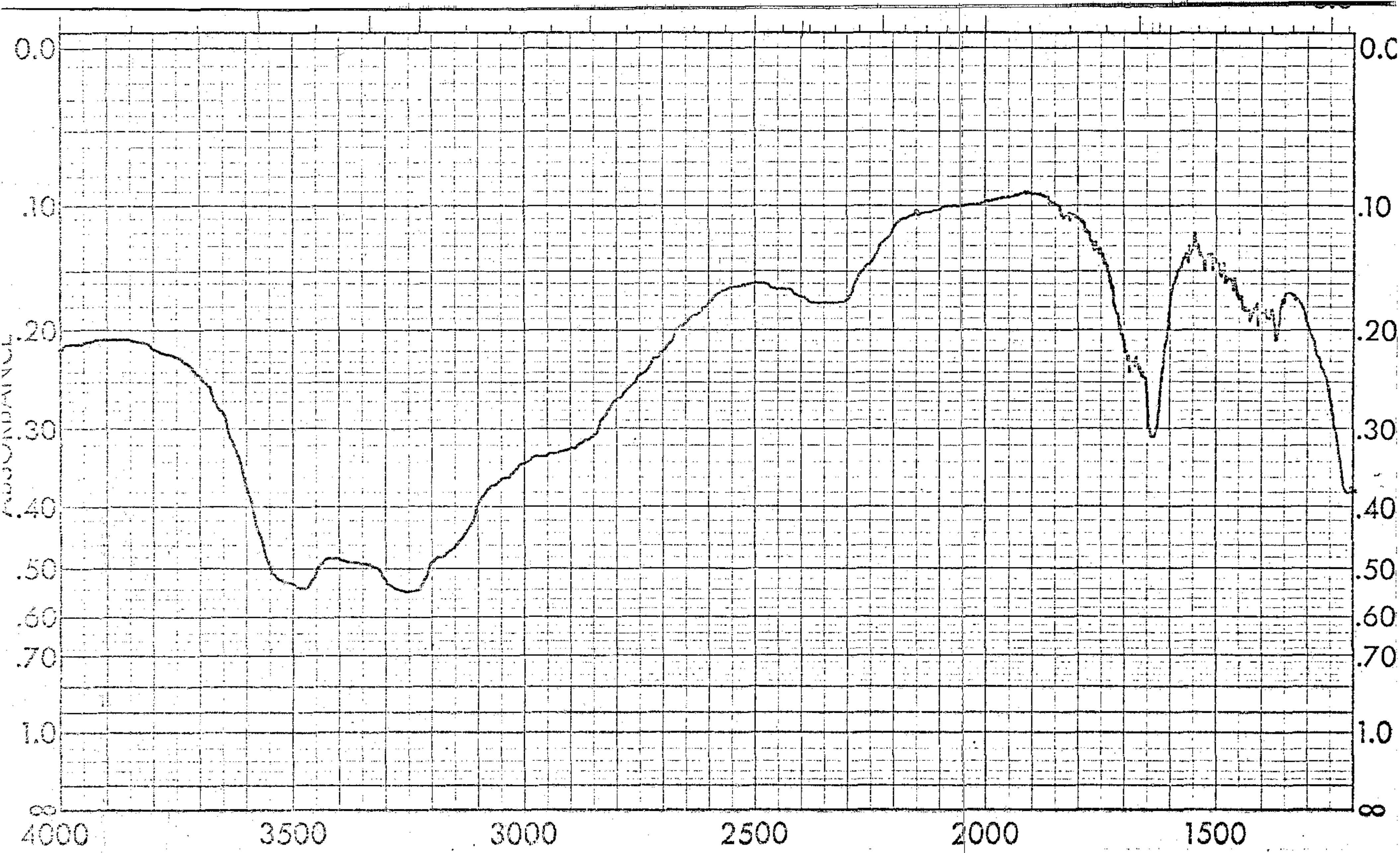
Spectrum No. 50: 50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Phosphate, $MgHPO_4$, and 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ By Transmission I.R.



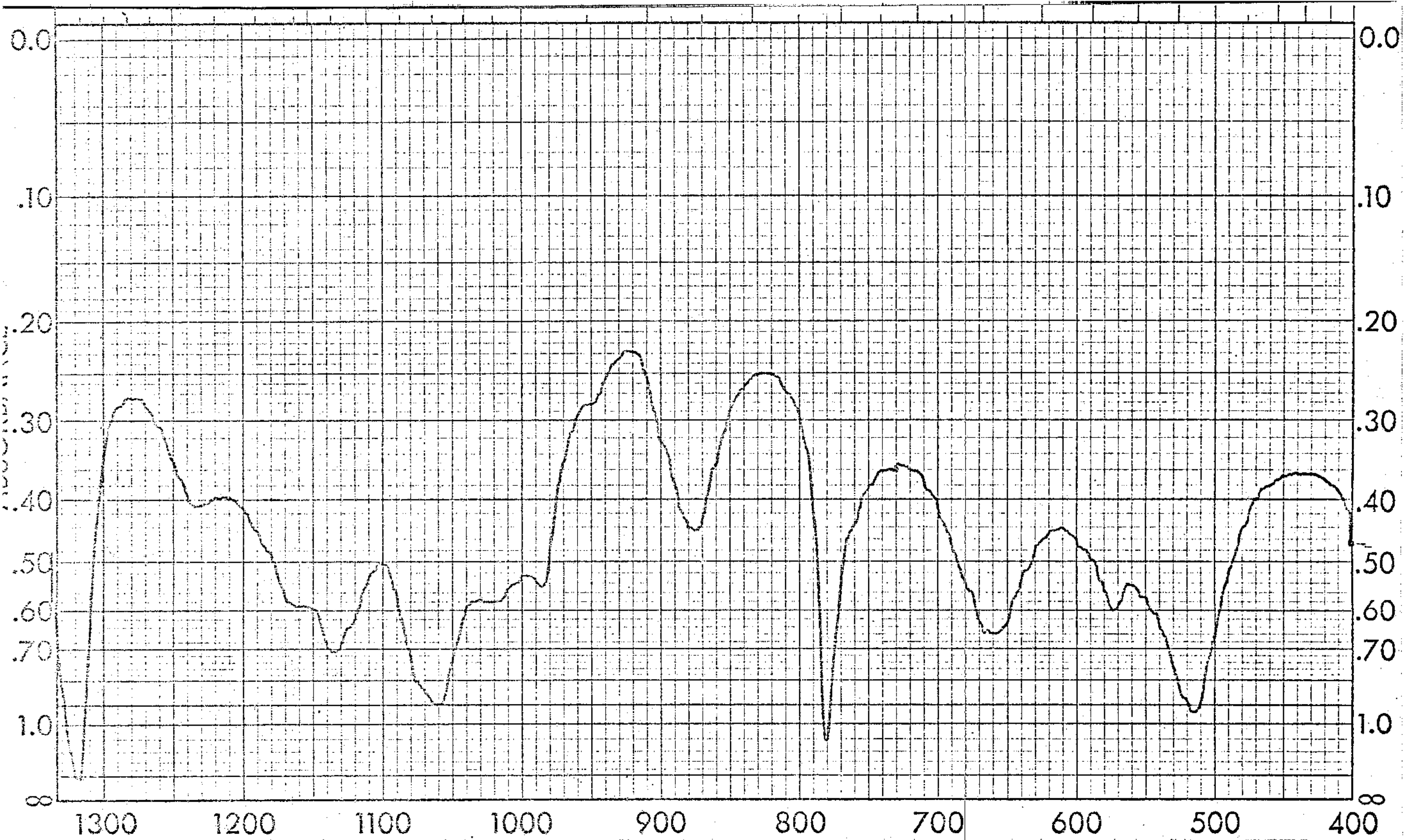
Spectrum No. 50: 50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Phosphate, $MgHPO_4$, and 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ By Transmission I.R.



Spectrum No. 51: 50% Magnesium Phosphate, $MgHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.

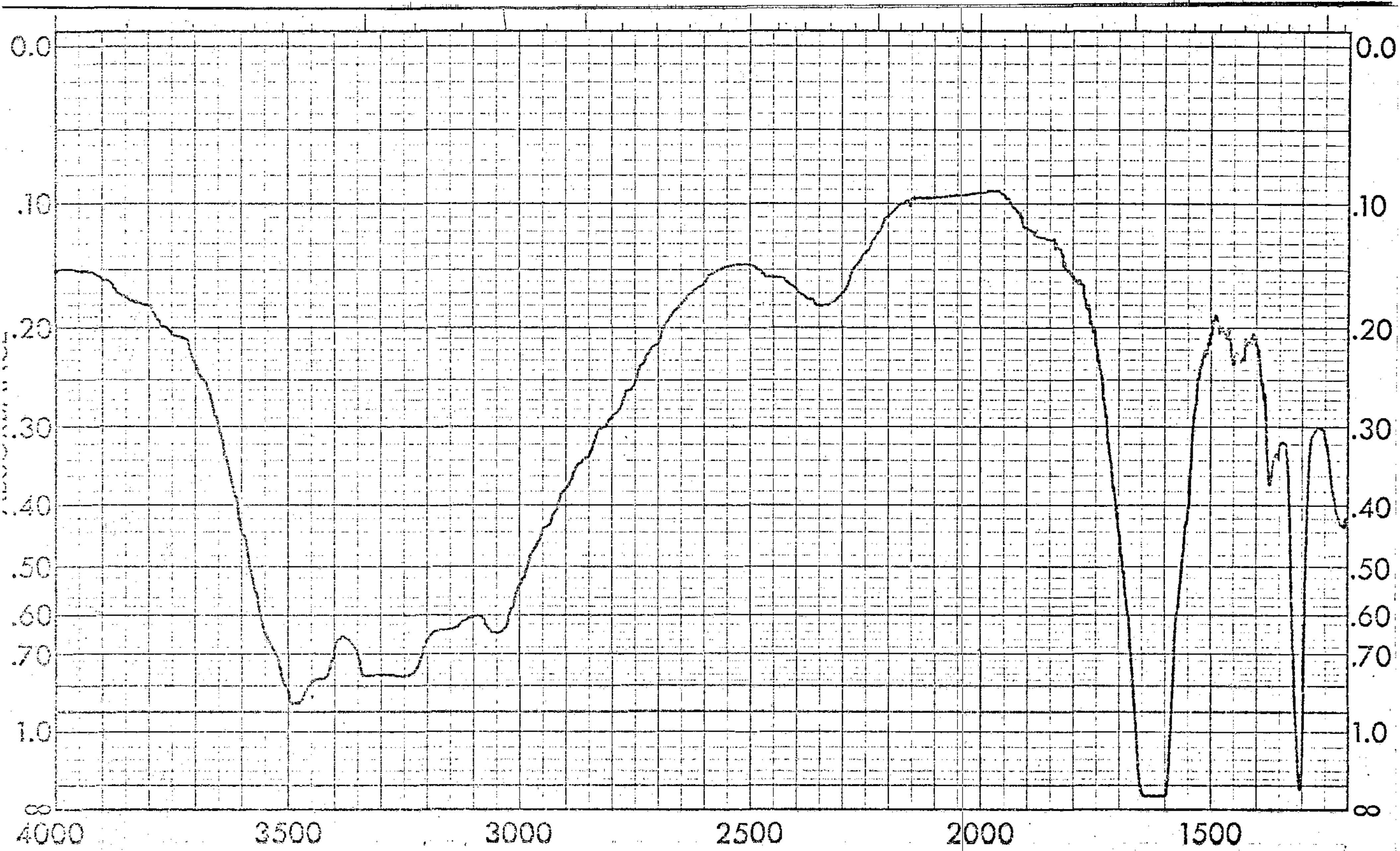


Spectrum No. 51: 50% Magnesium Phosphate, $MgHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Hydrogen Phosphate, $CaHPO_4$ By Transmission I.R.



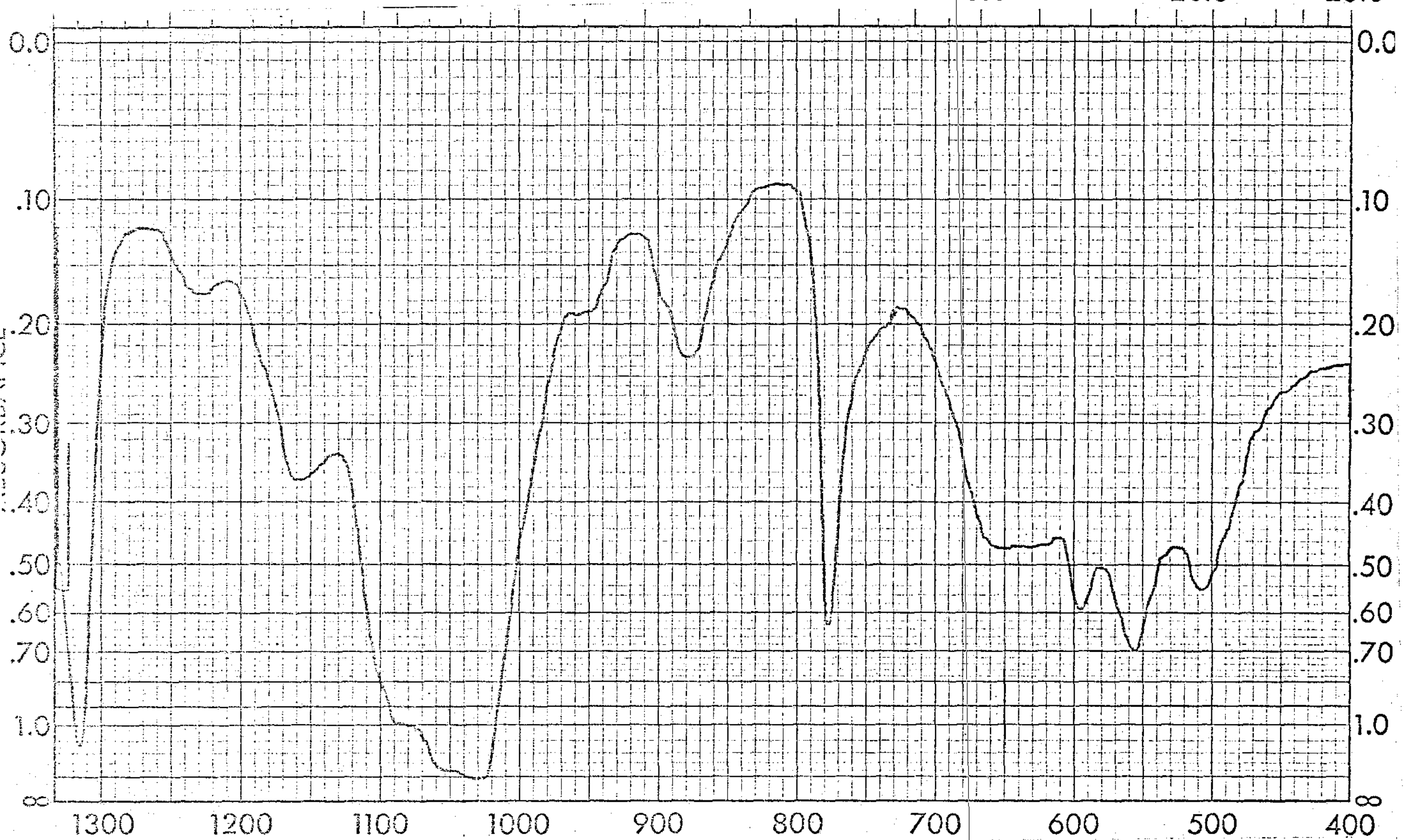
Spectrum No. 52: 25% Magnesium Phosphate, $MgHPO_4$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$

By Transmission I.R.

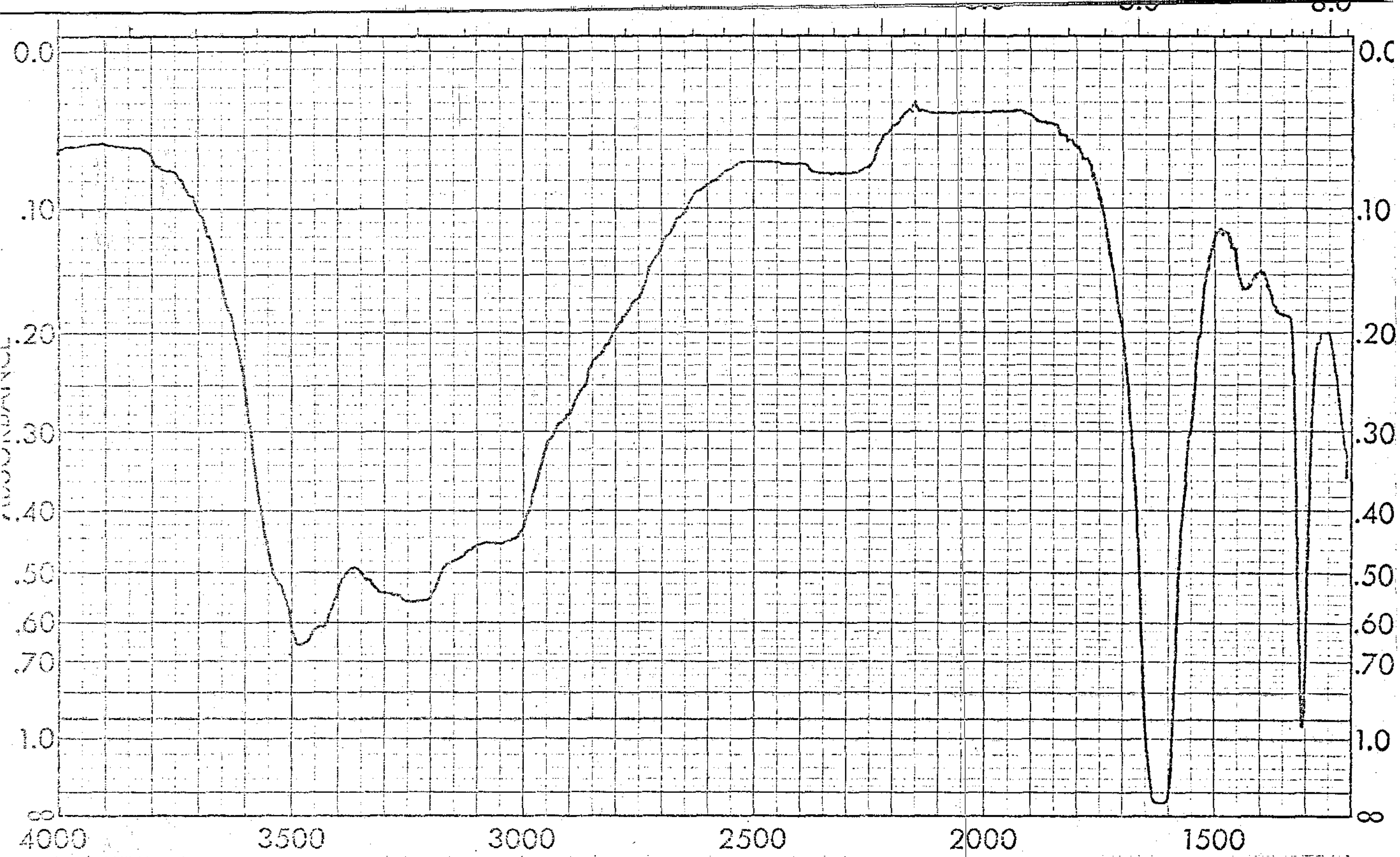


Spectrum No. 52: 25% Magnesium Phosphate, $MgHPO_4$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$

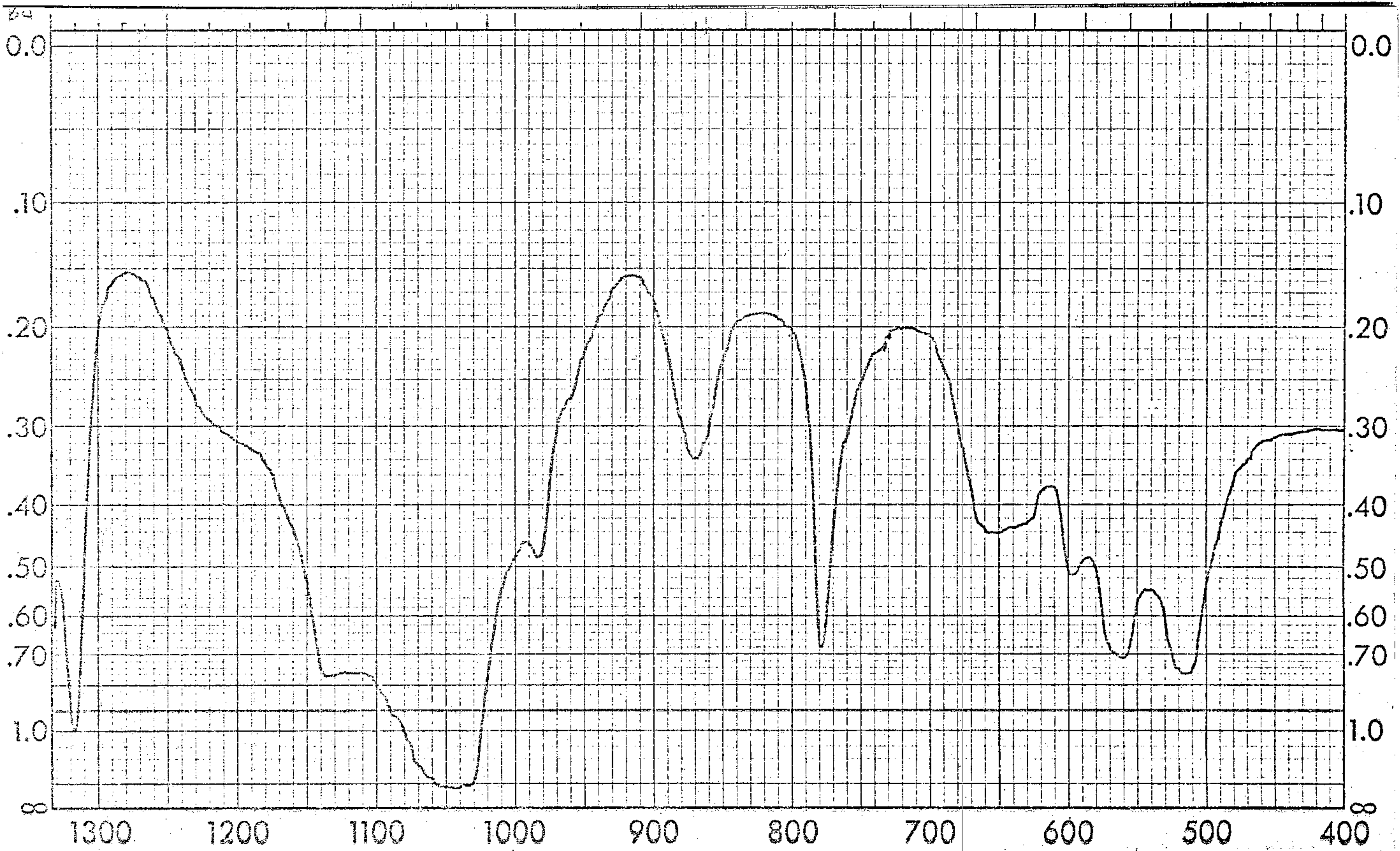
By Transmission I.R.



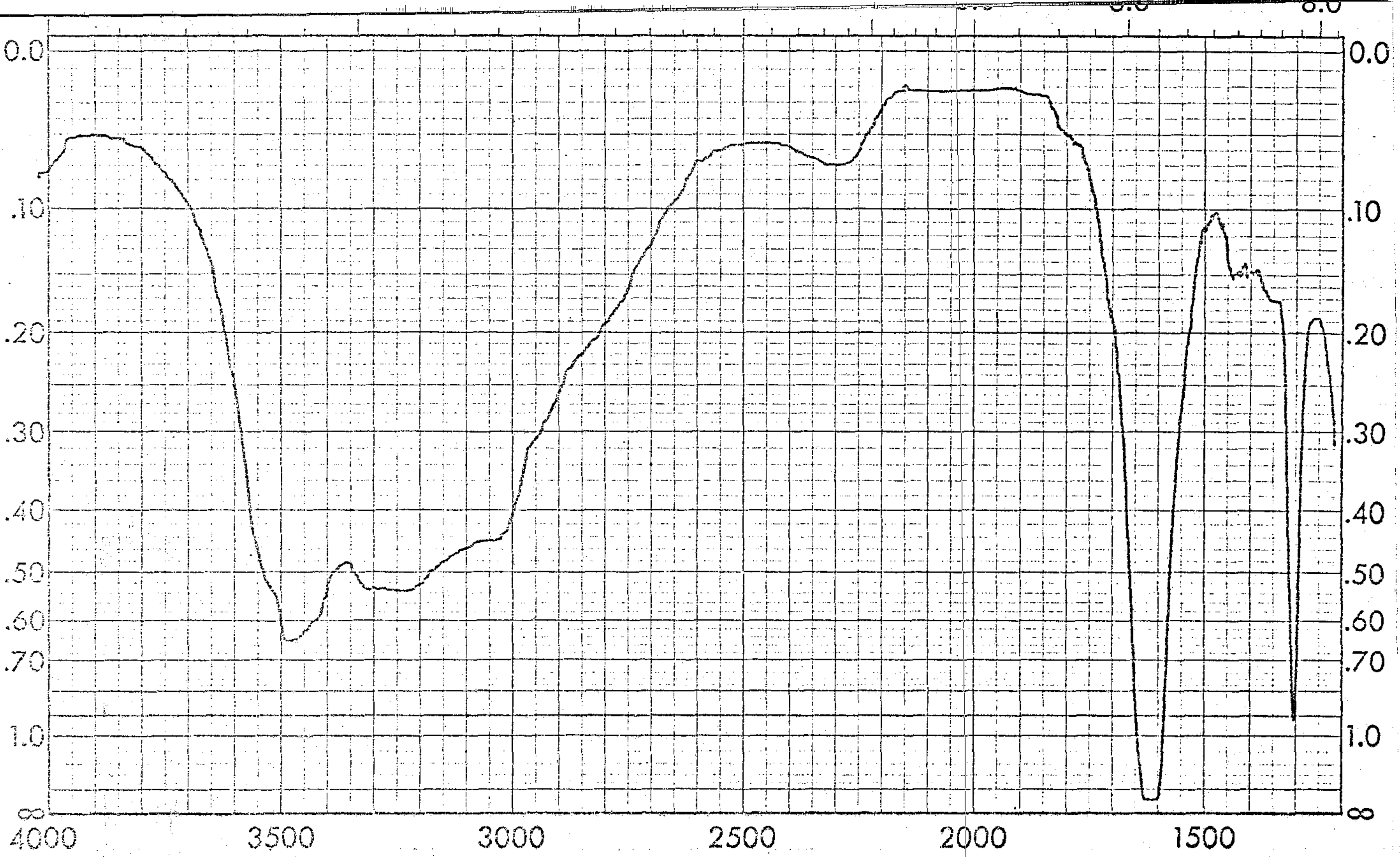
Spectrum No. 53: 25% Tricalcium Phosphate, $CaC_3(PO_4)_2$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



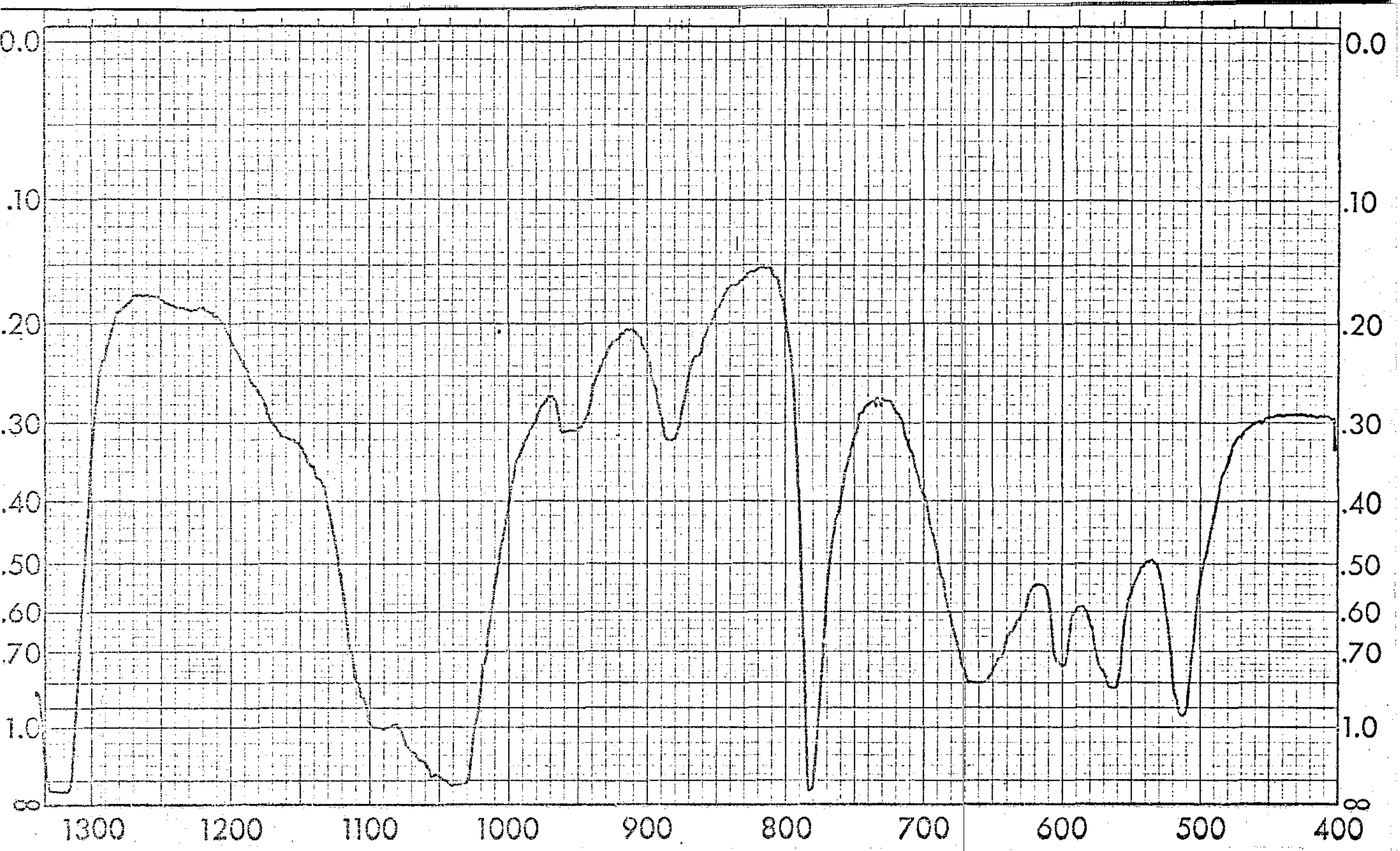
Spectrum No. 53: 25% Tricalcium Phosphate, $CaC_3(PO_4)_2$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate, $MgHPO_4$



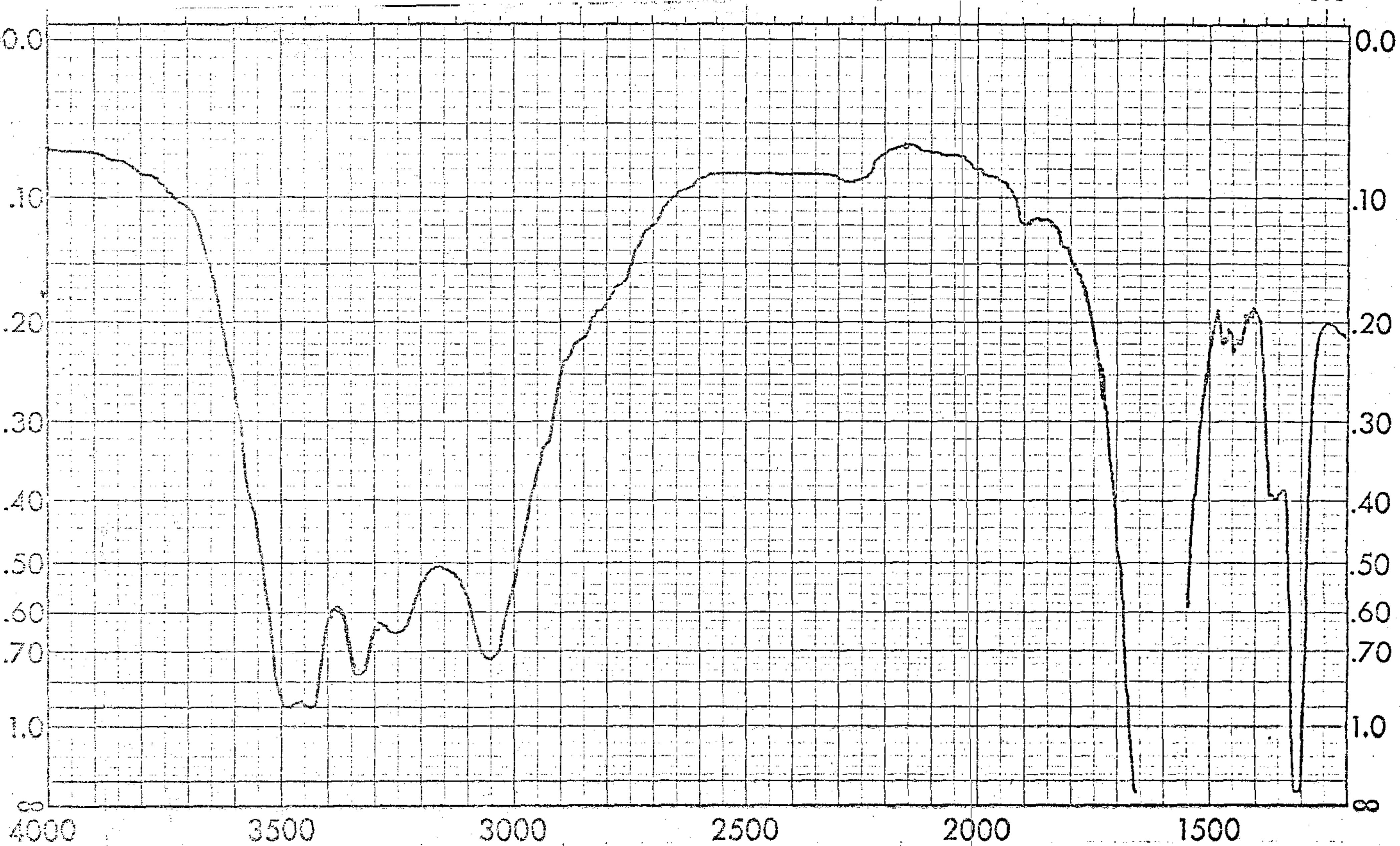
Spectrum No. 54: 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Calcium Oxalate Monohydrate,



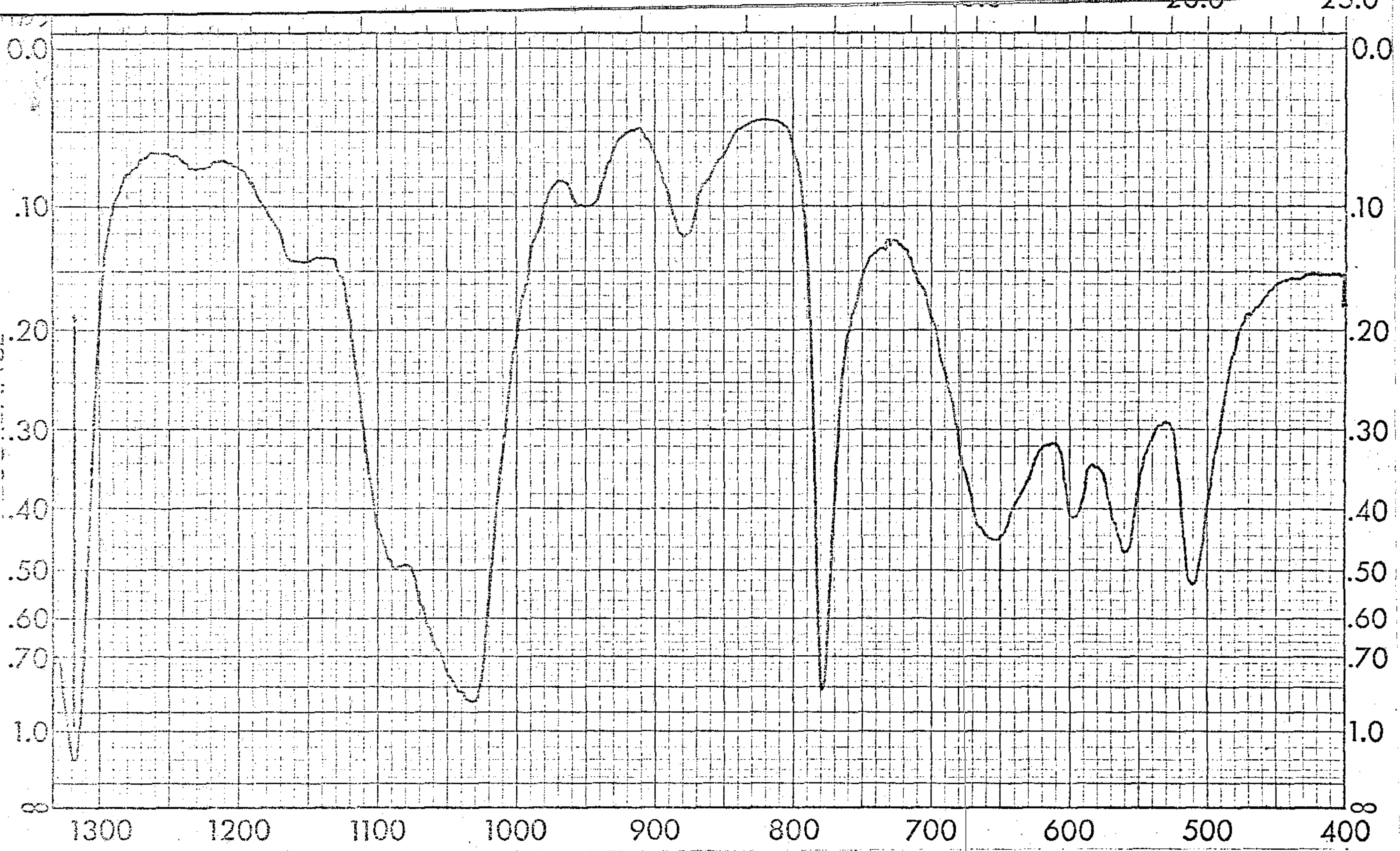
Spectrum No. 54: 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Calcium Oxalate Monchydrate, $CaC_2O_4 \cdot H_2O$ By Transmission I.R.



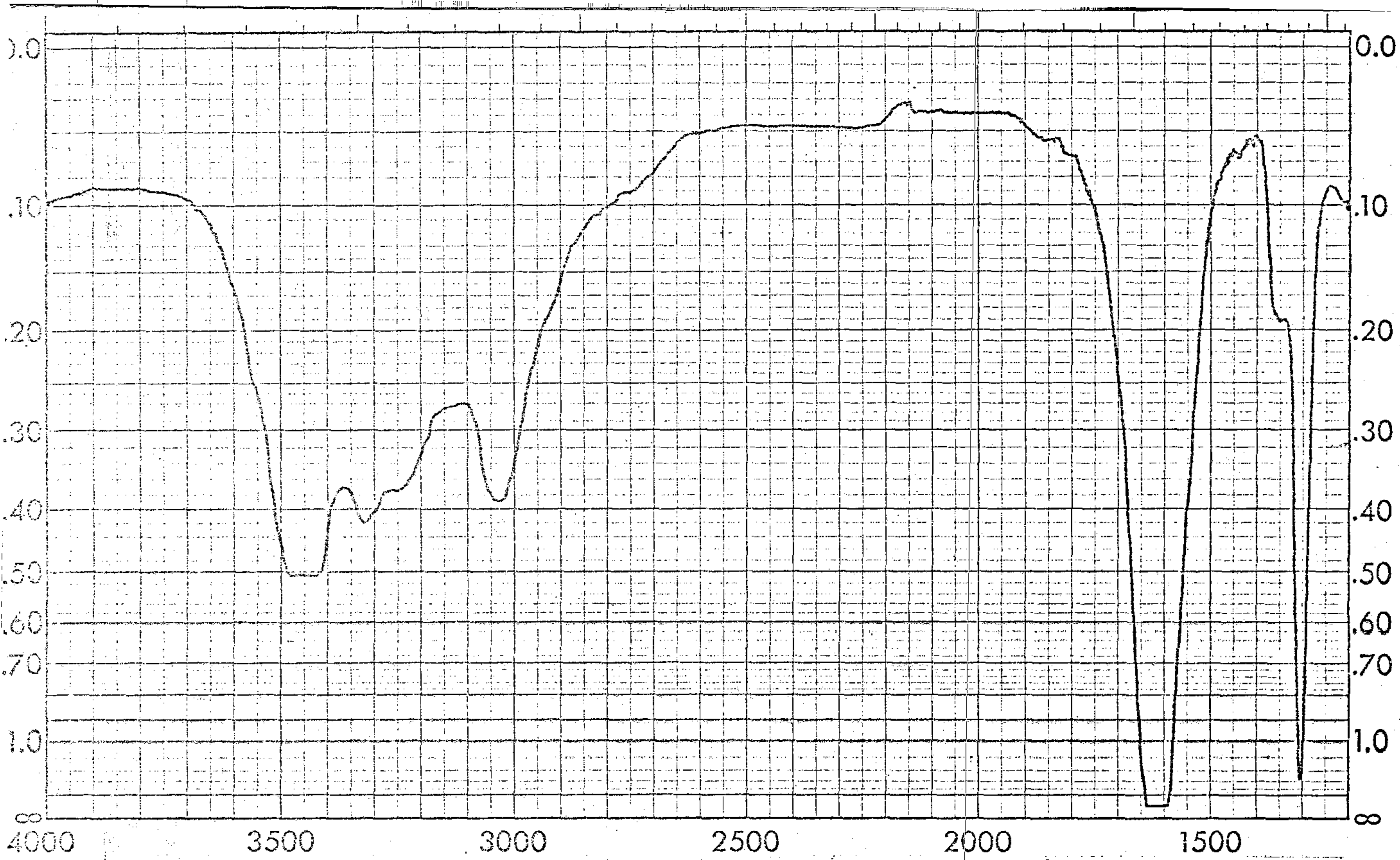
Spectrum No. 55: 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ By Transmission I.R.



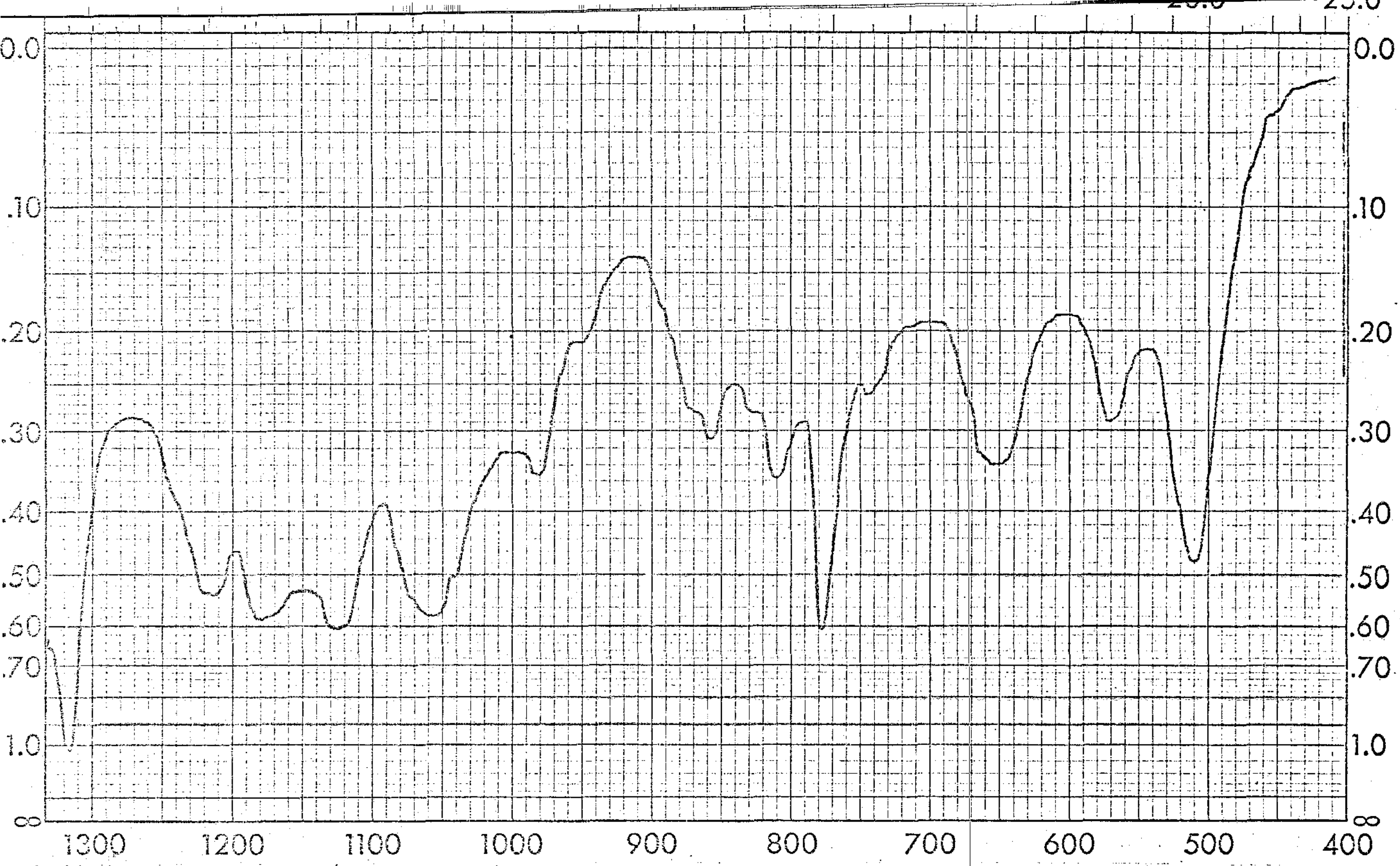
Spectrum No. 55: 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ BY Transmission I.R.



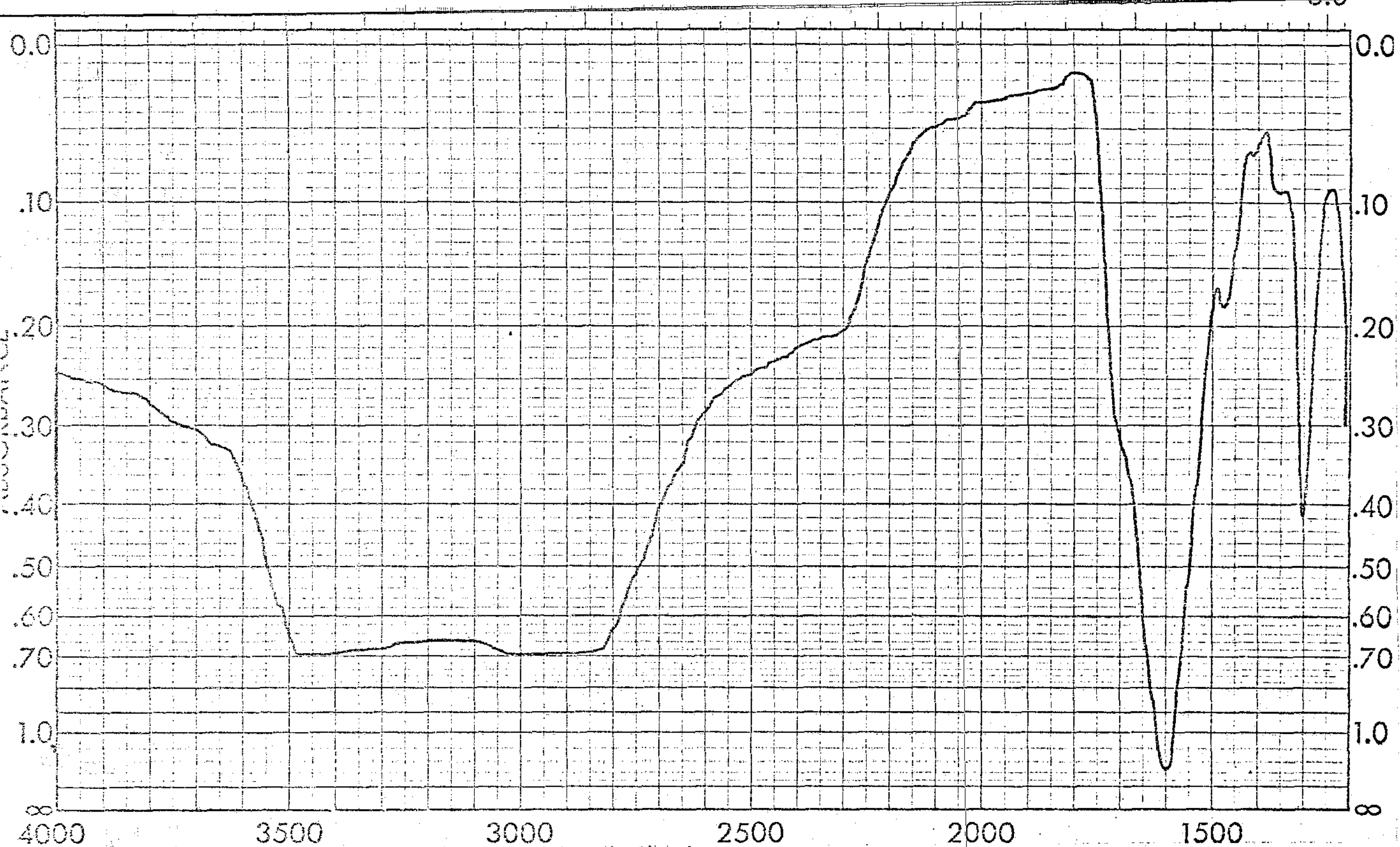
Spectrum No. 56: 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



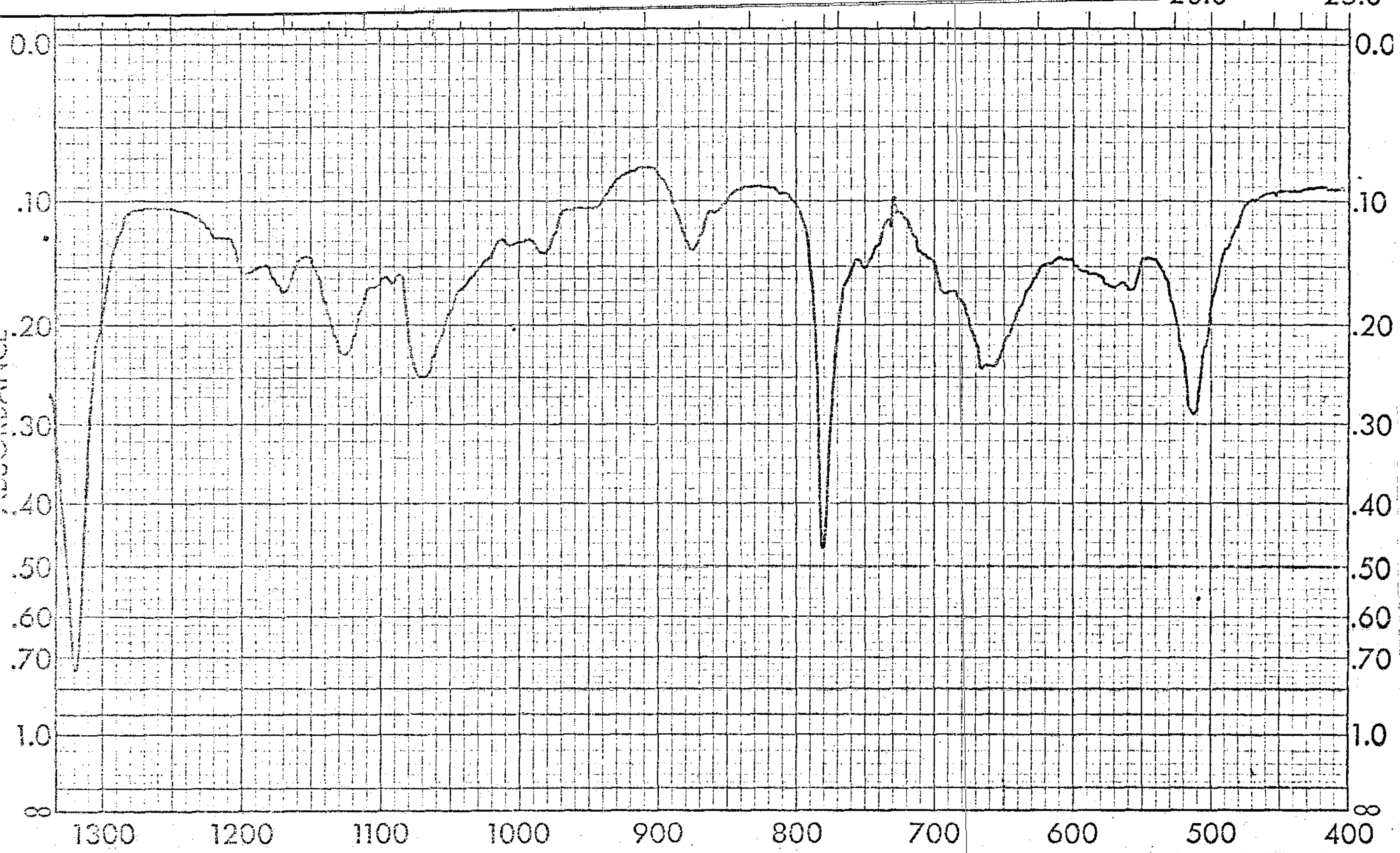
Spectrum No. 56: 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



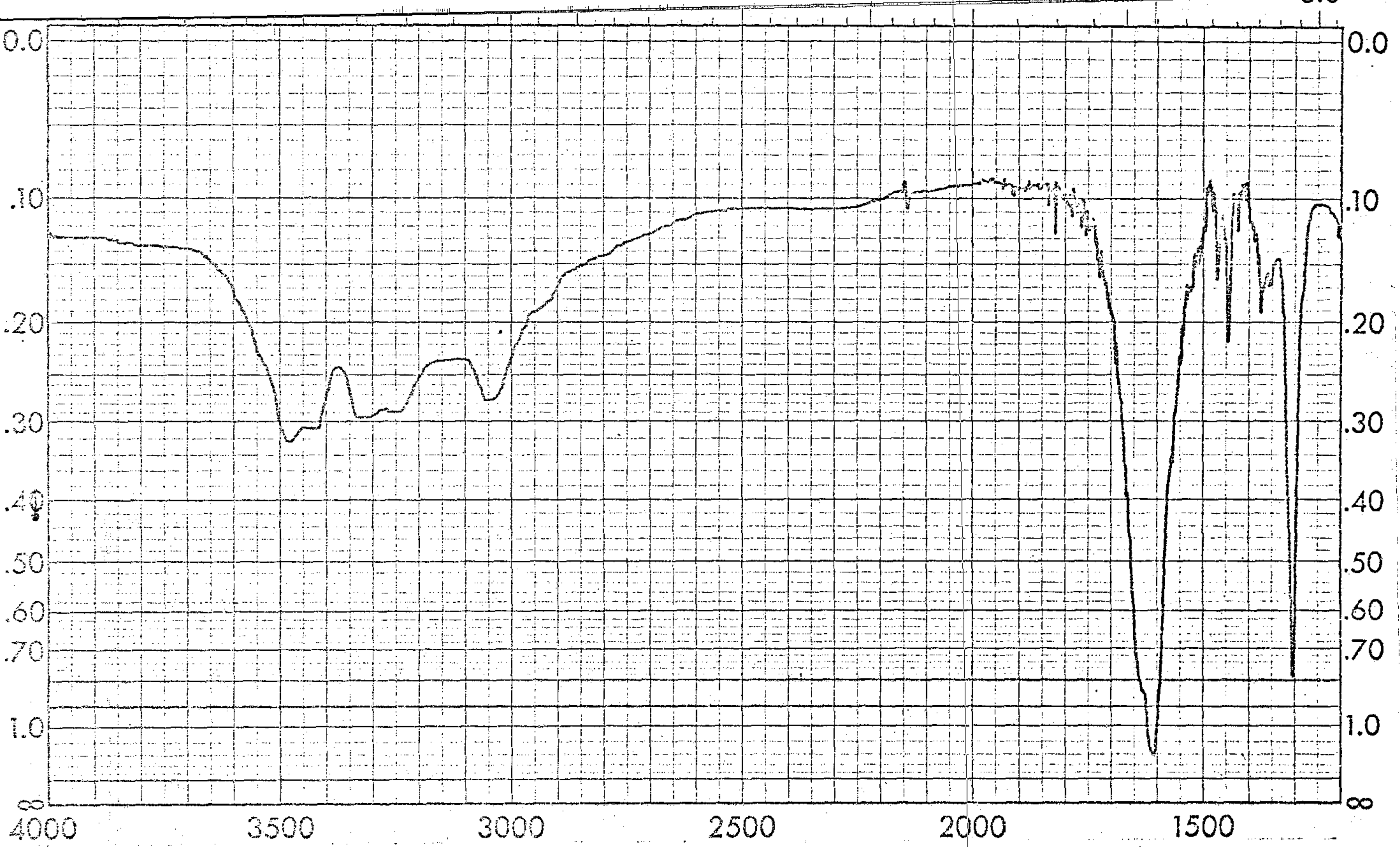
Spectrum No. 57: 25% Cystine, $SCH_2CH(NH_2)$-COOH, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, and 25% Magnesium Phosphate, $MgHPO_4$



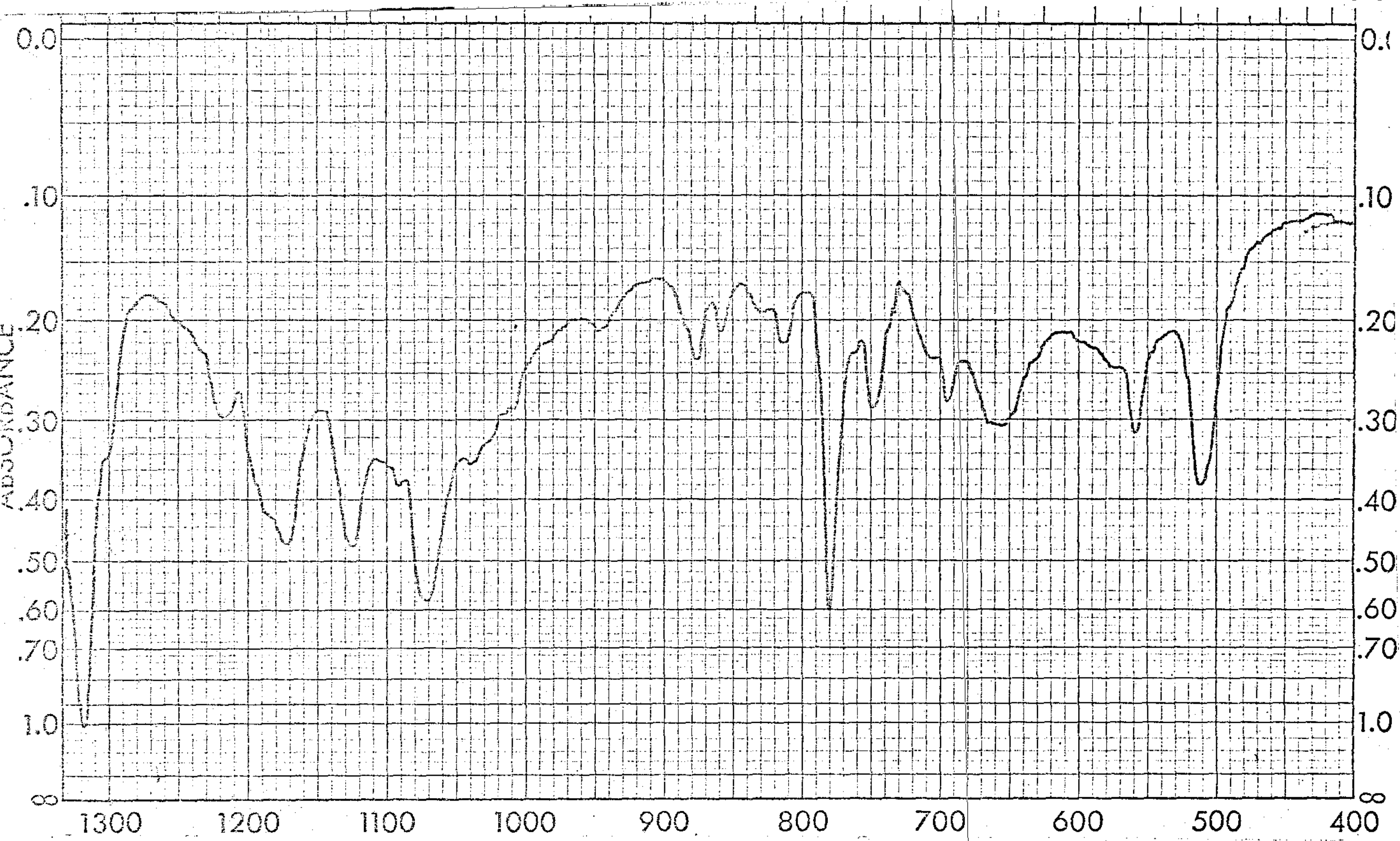
Spectrum No. 57: 25% Cystine, $SCH_2CH(NH_2)$-COOH, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, and 25% Magnesium Phosphate, $MgHPO_4$



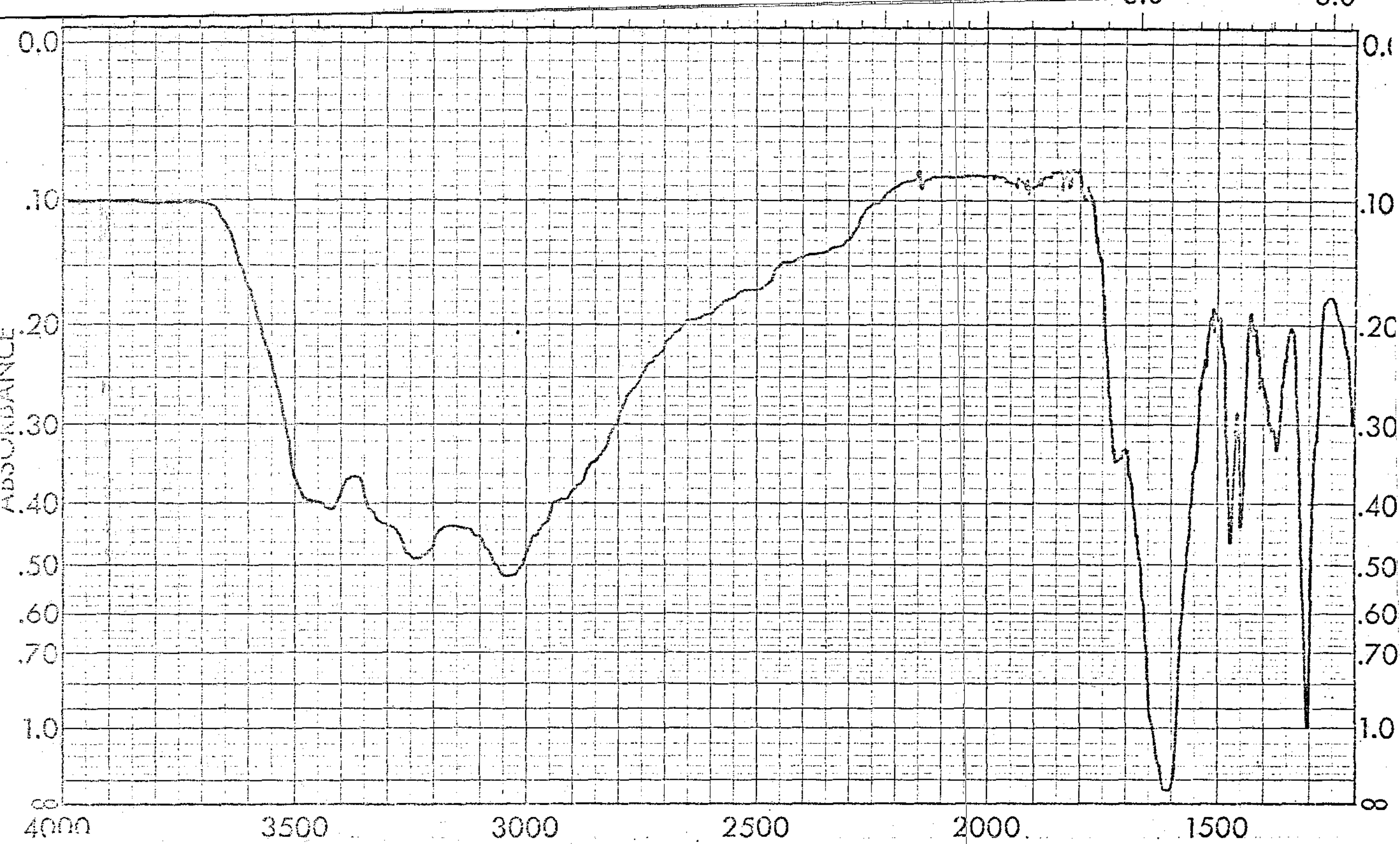
Spectrum No. 58: 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, and 25% Indigo, $C_{16}H_{10}N_2O_2$ By Transmission I.R.



Spectrum No. 58: 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, and 25% Indigo, $C_{16}H_{10}N_2O_2$ By Transmission I.R.

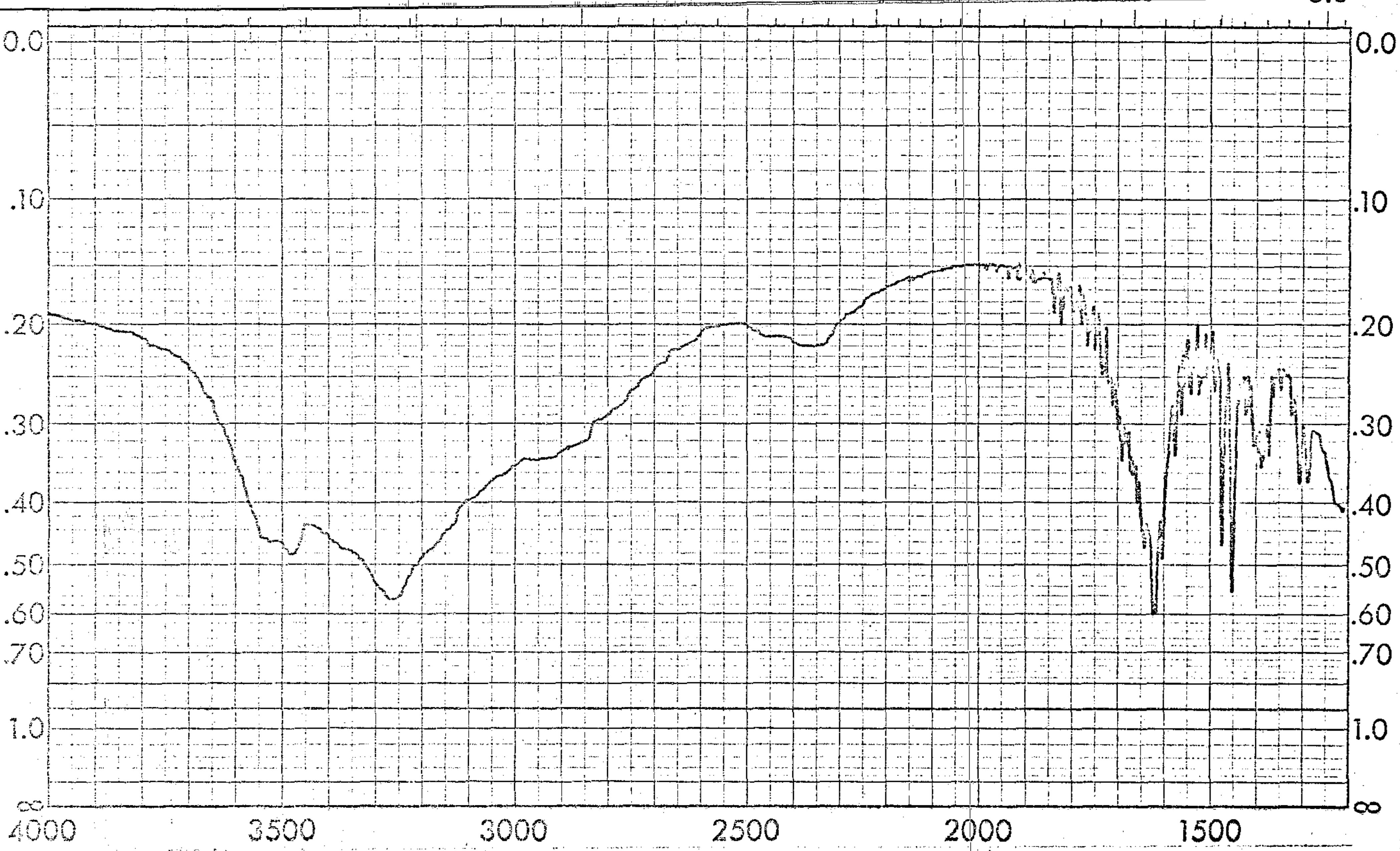


Spectrum No. 59: 25% Indigo, $C_{16}H_{10}N_2O_2$, 25% Cystine, $SCH_2CH(NH_2)-COOH$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ By Transmission I.R.

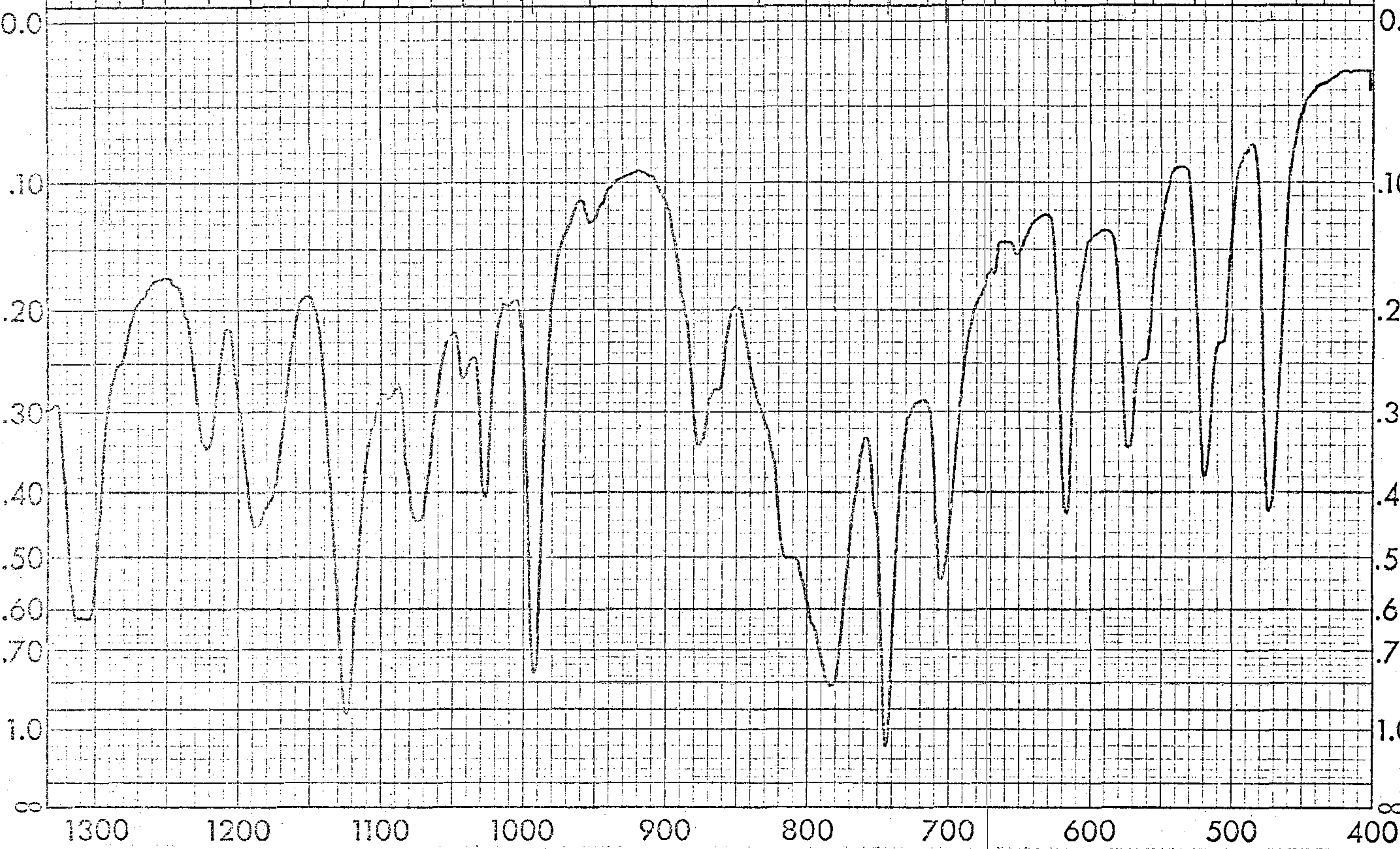


Spectrum No. 59: 25% Indigo, $C_{16}H_{10}N_2O_2$, 25% Cystine, $SCH_2CH(NH_2)$-COOH, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ By Transmission I.R.

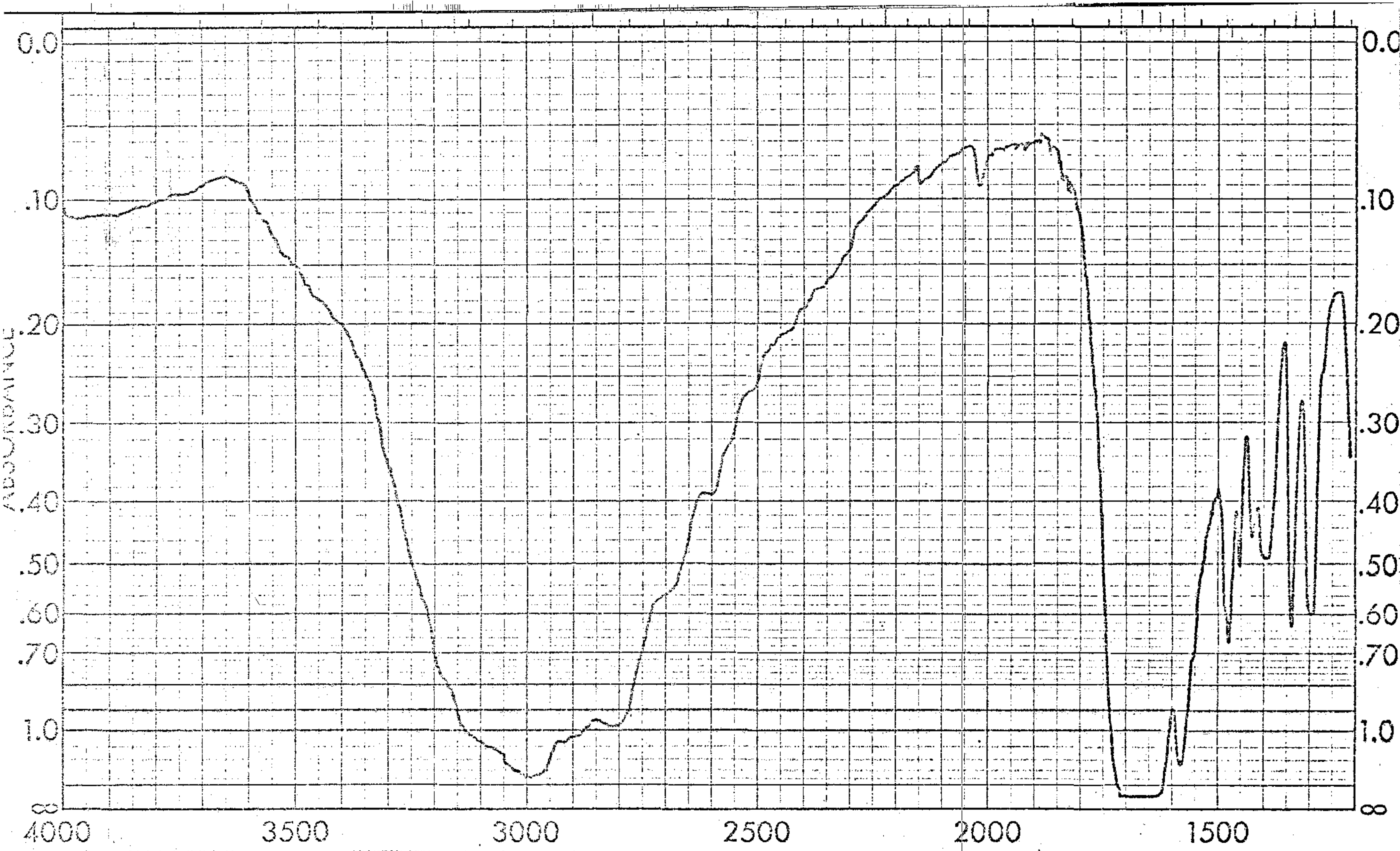
Spectrum No. 60: 25% Indigo, $C_{16}H_{10}N_2O_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



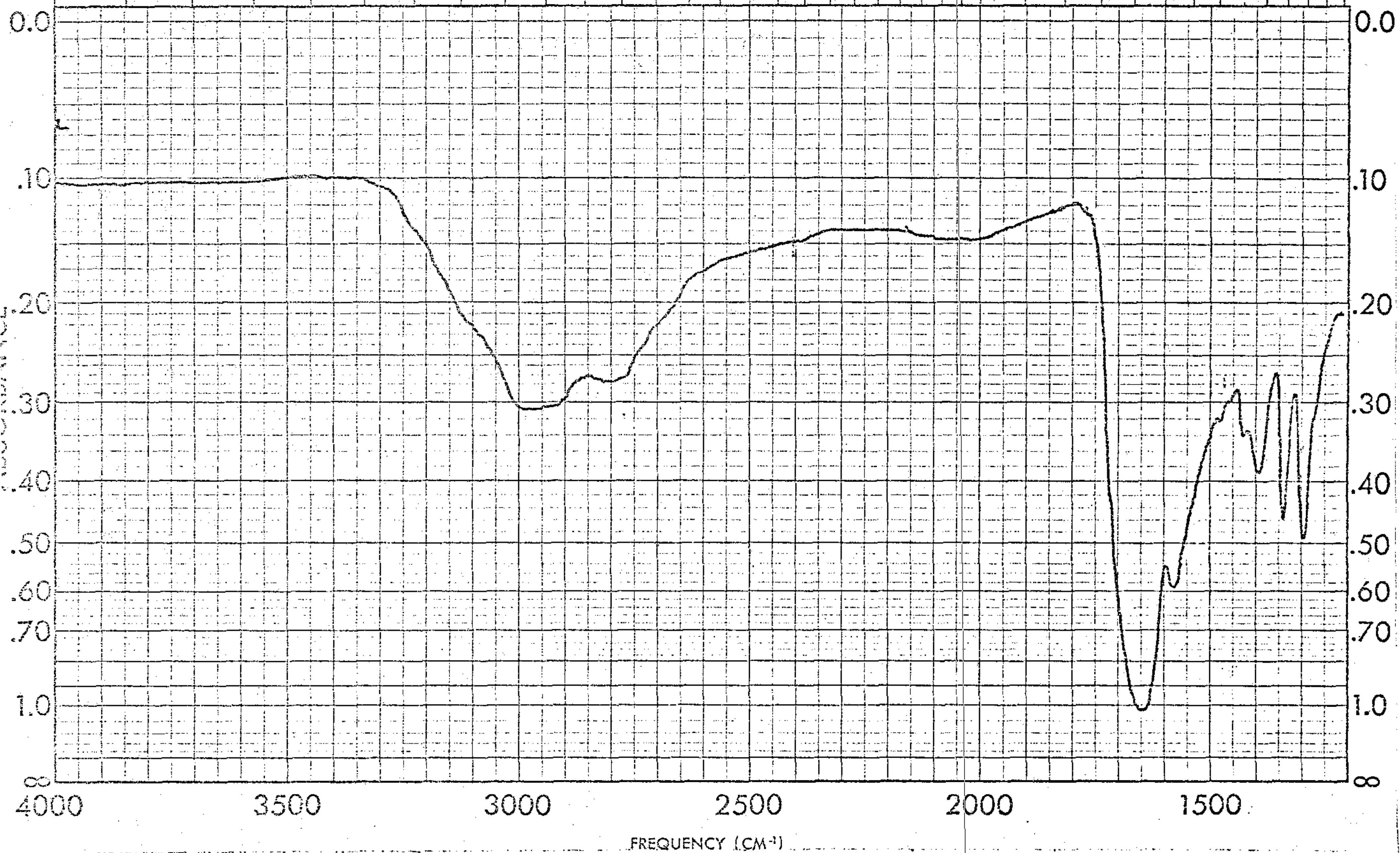
Spectrum No. 60: 25% Indigo, $C_{16}H_{10}N_2O_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ By Transmission I.R.



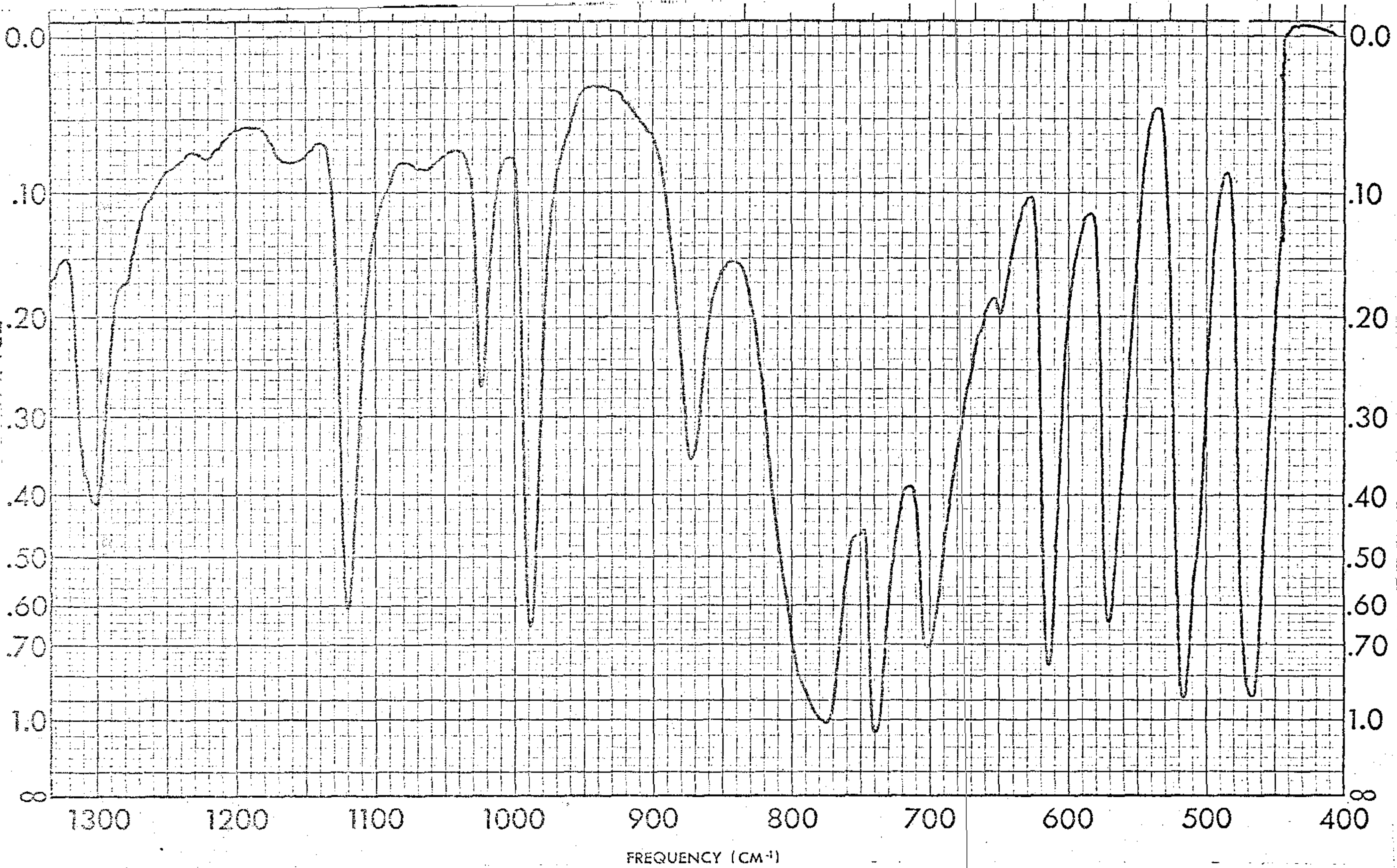
Spectrum No. 61: 50% Uric Acid, $C_5H_4N_4O_3$, 25% Indigo, $C_{16}H_{10}N_2O_2$, and 25% Cystine, $SCH_2CH(NH_2)$-COOH By Transmission I.R.



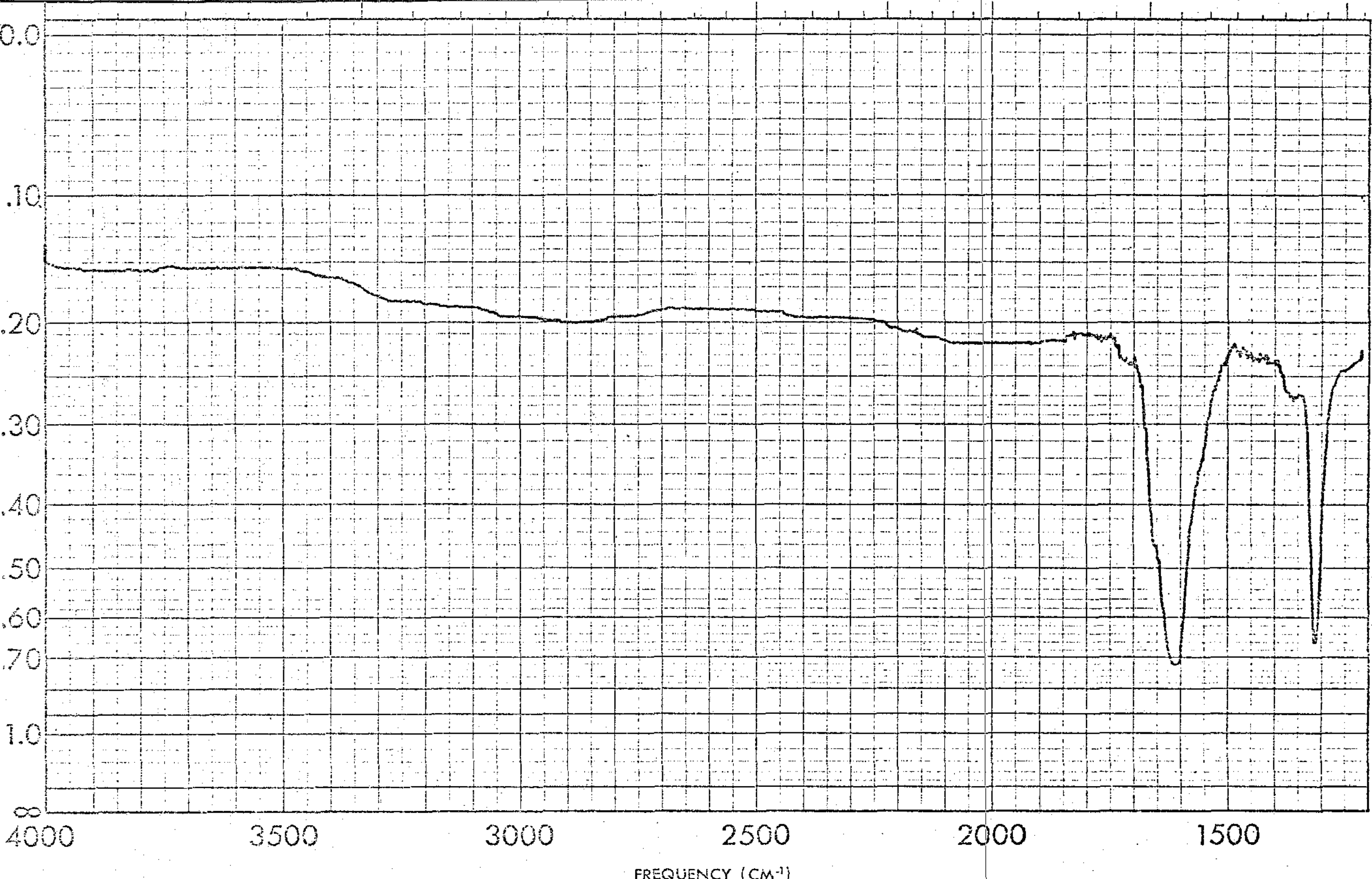
Spectrum No. 61: 50% Uric Acid, $C_5H_4N_4O_3$, 25% Indigo, $C_{16}H_{10}N_2O_2$, and 25% Cystine, $SCH_2CH(NH_2)$-COOH By Transmission I.R.



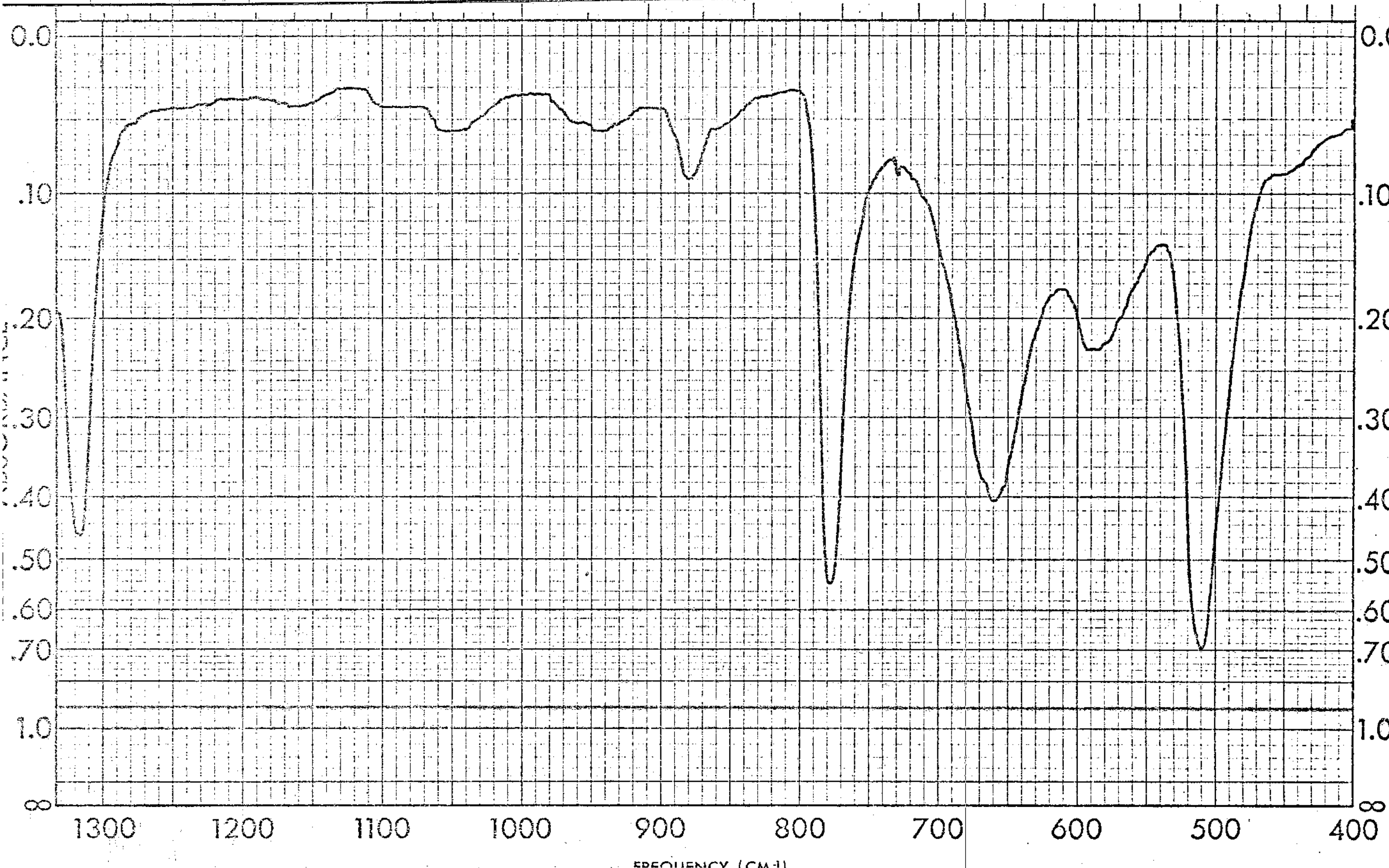
Spectrum No. 62: Uric Acid, $C_5H_4N_4O_3$ by A.T.R.



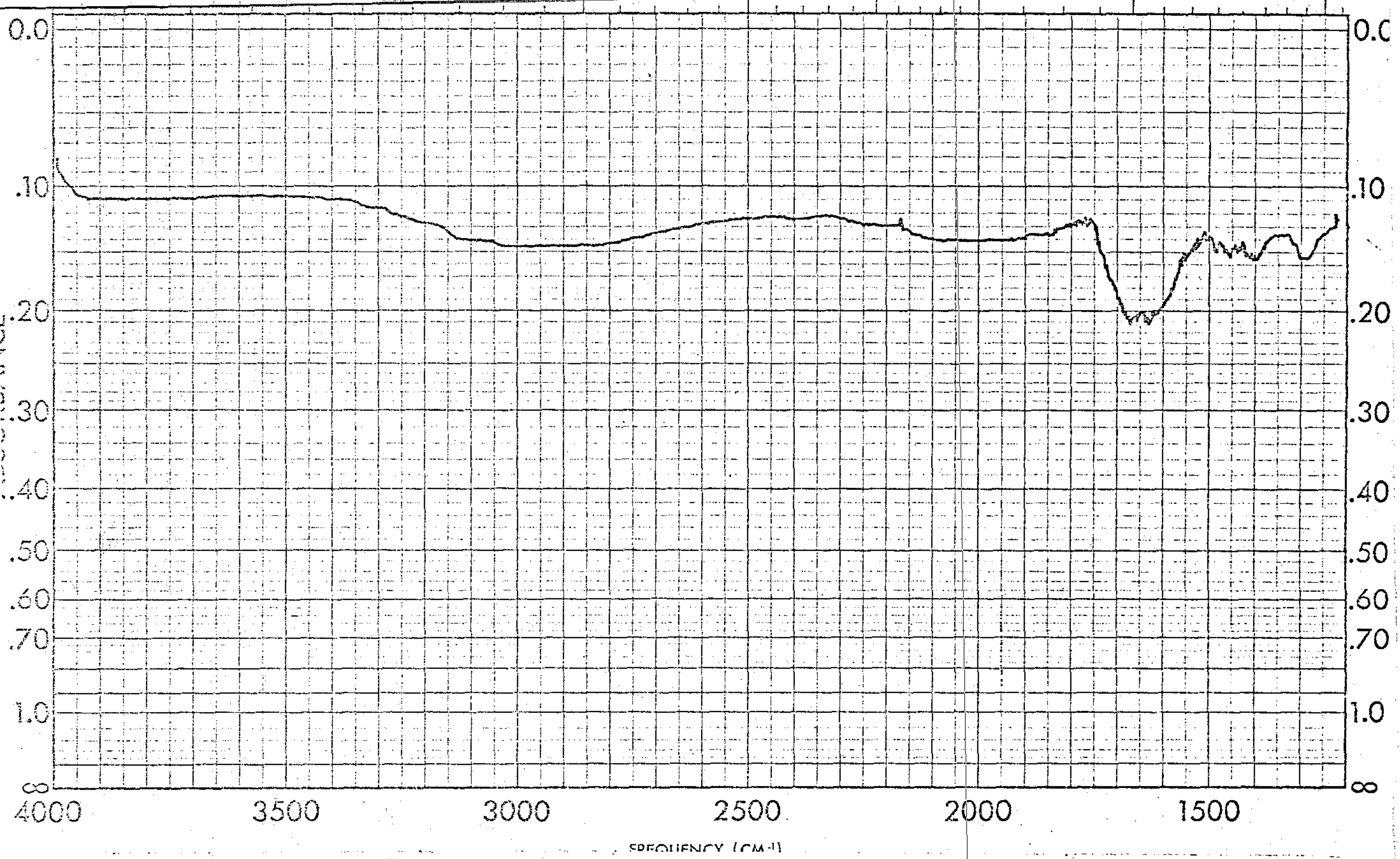
Spectrum No. 62: Uric Acid, $C_5H_4N_4O_3$ by A.T.R.



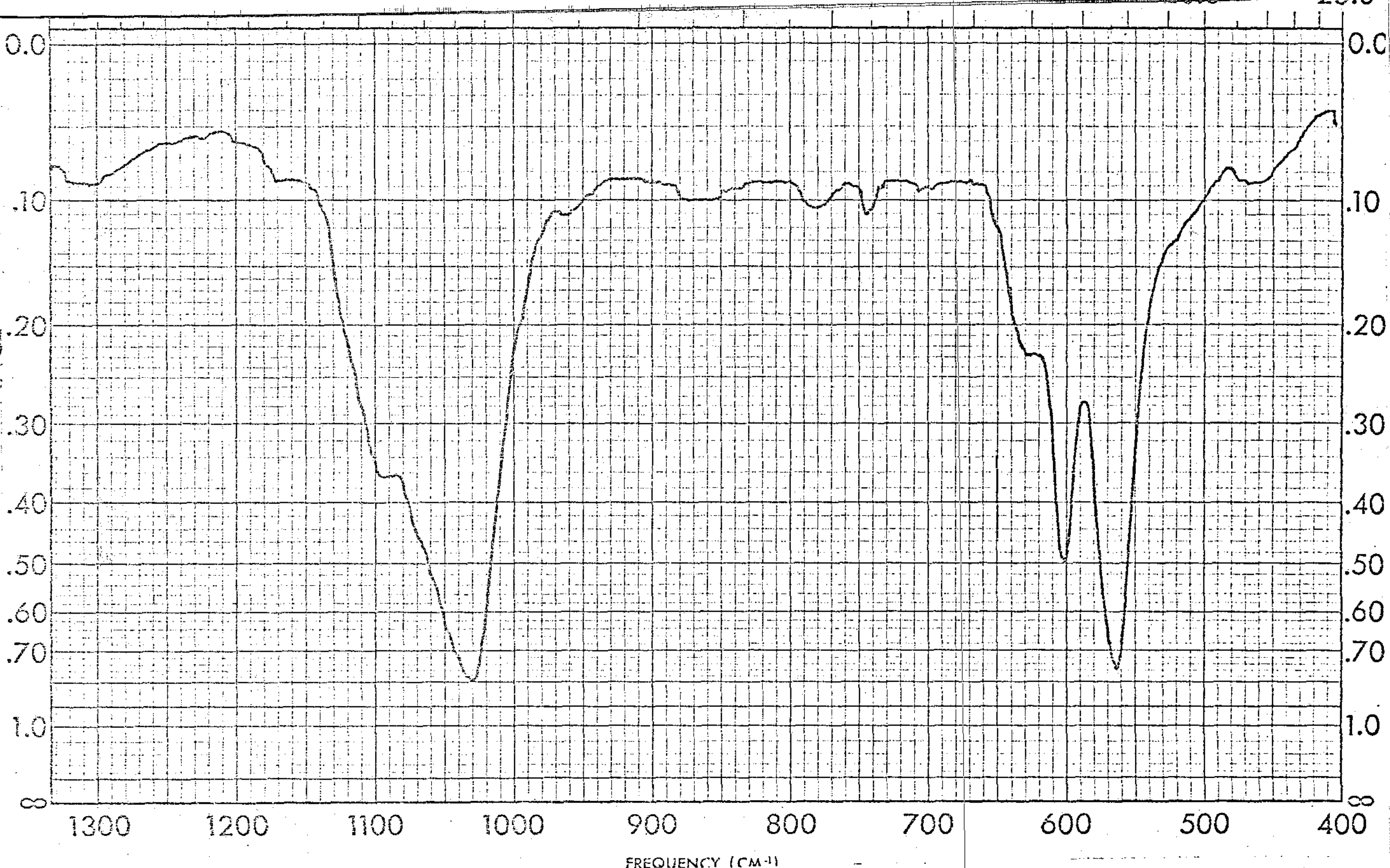
Spectrum No. 63: Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ by A.T.R.



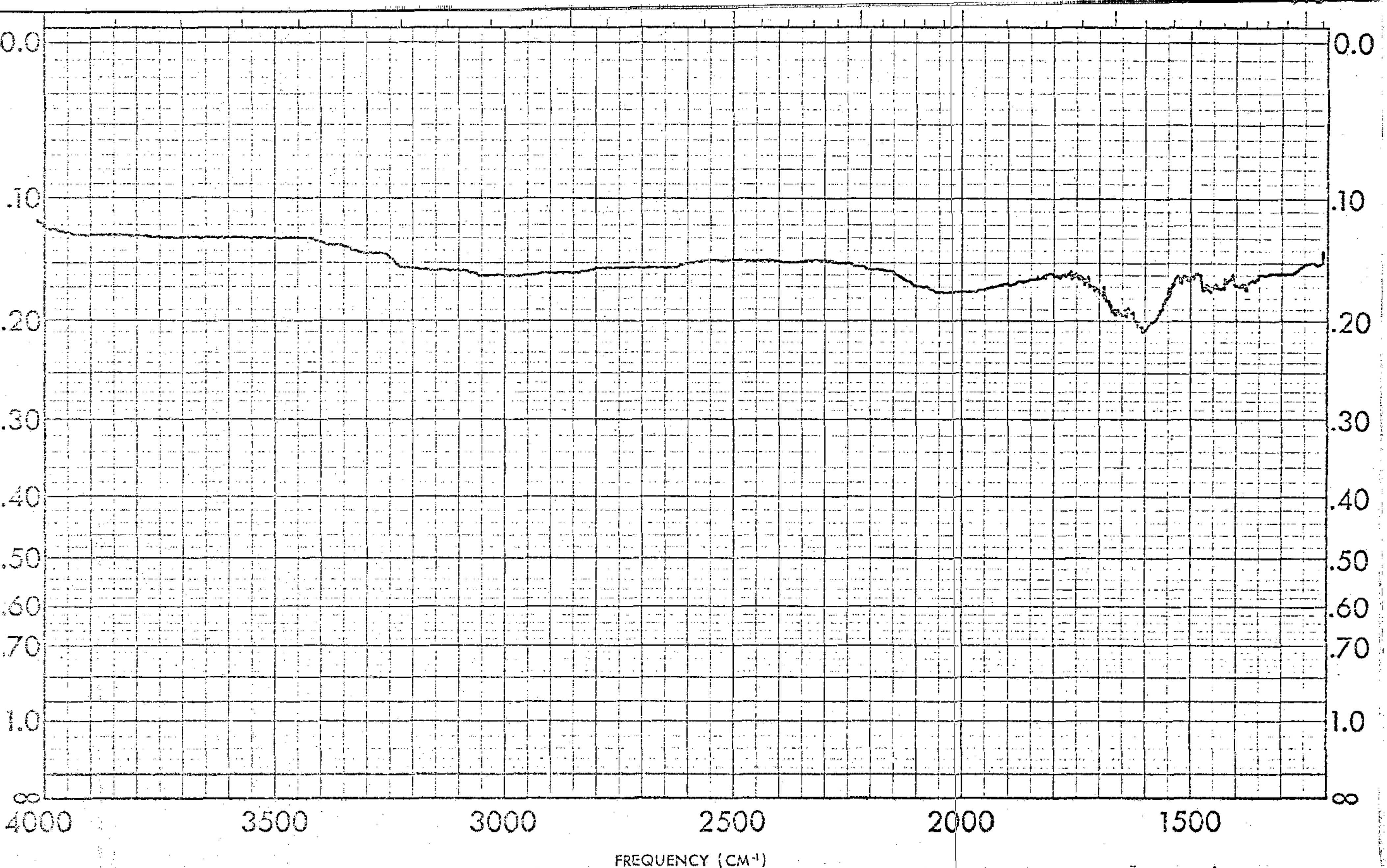
Spectrum No. 63: Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ by A.T.R.



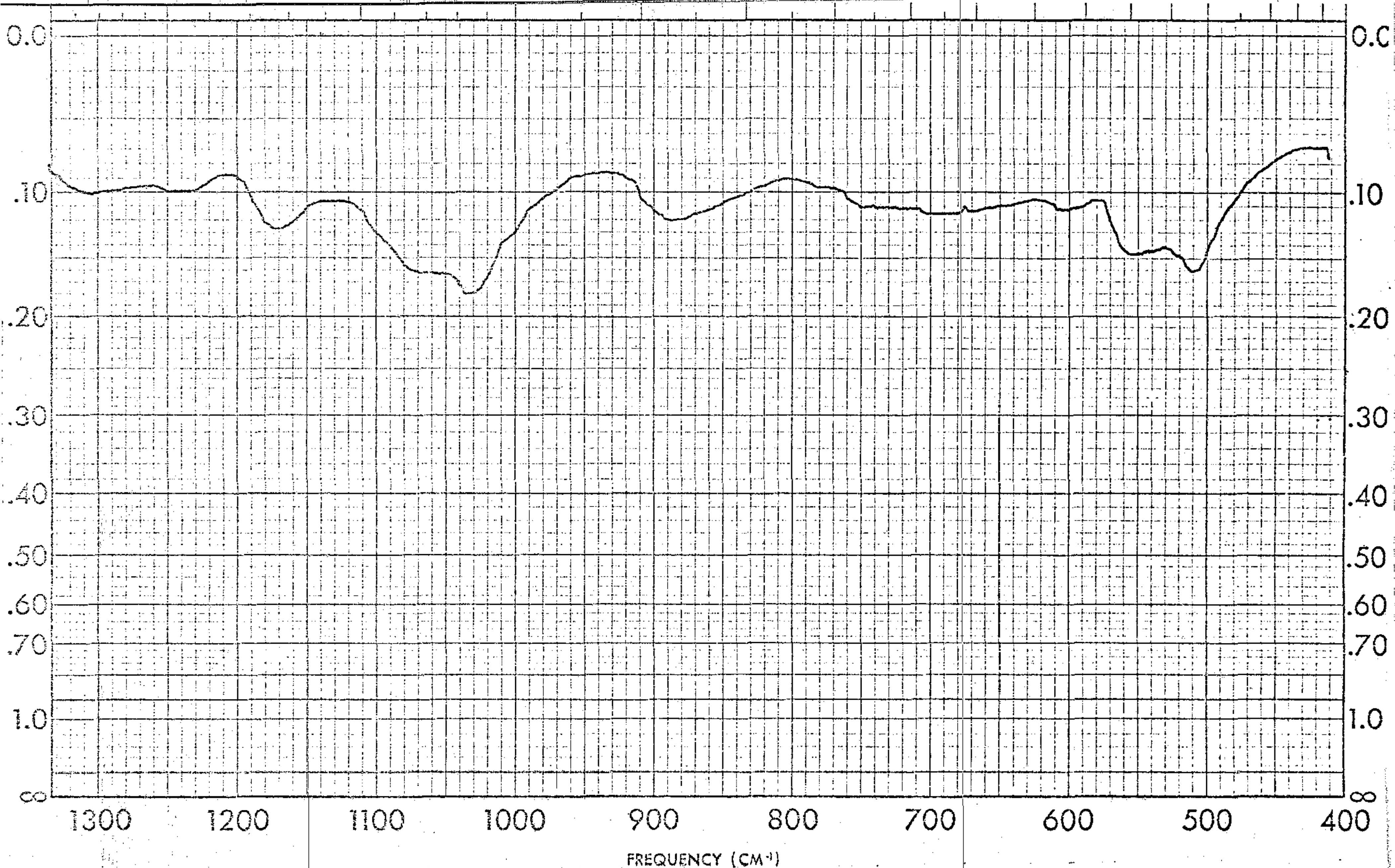
Spectrum No. 64: Tricalcium Phosphate, $Ca_3(PO_4)_2$ by A.T.R.



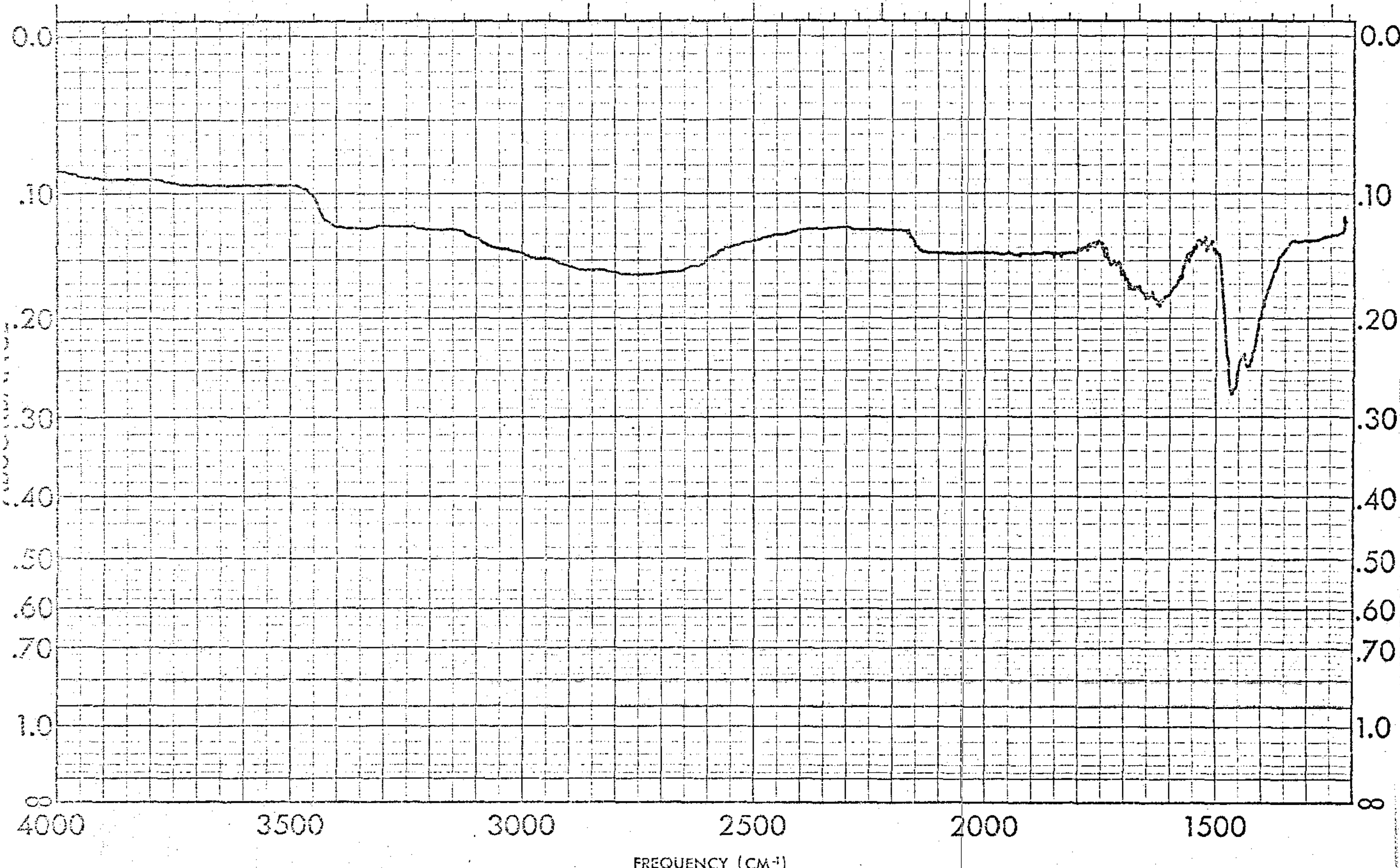
Spectrum No. 64: Tricalcium Phosphate, $Ca_3(PO_4)_2$ by A.T.R.



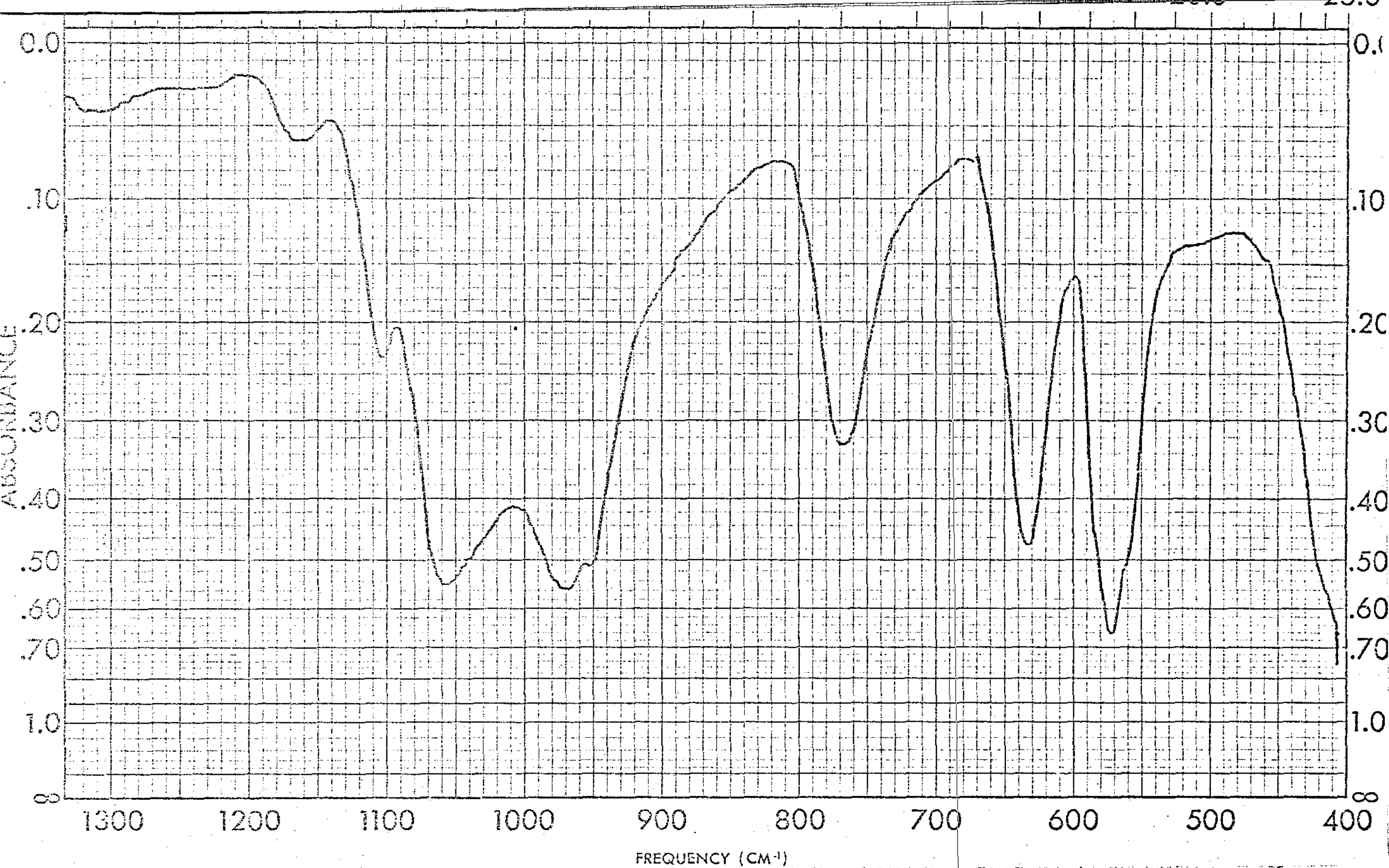
Spectrum No. 65: Magnesium Phosphate, $MgHPO_4$ by A.T.R.



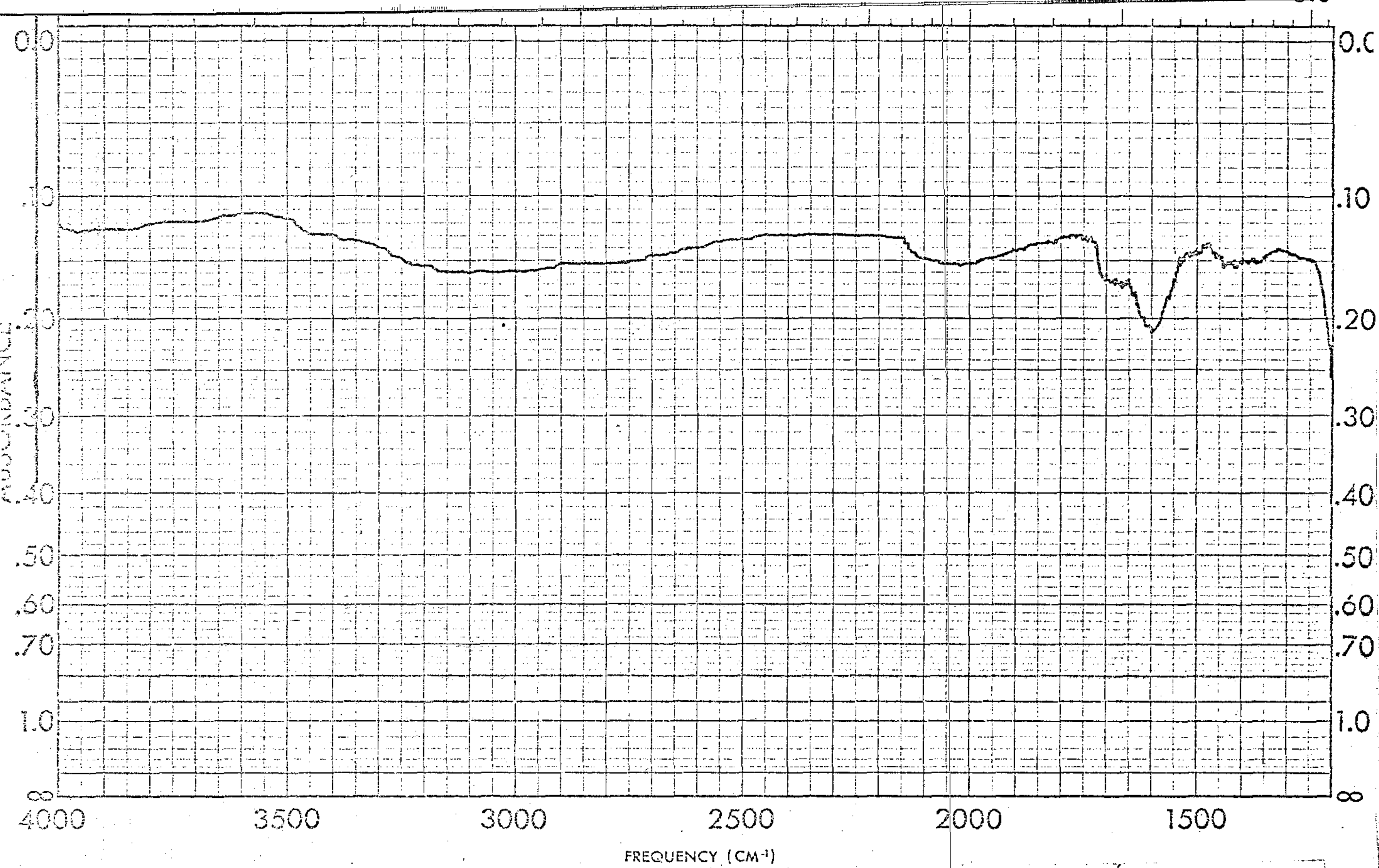
Spectrum No. 65: Magnesium Phosphate, $MgHPO_4$ by A.T.R.



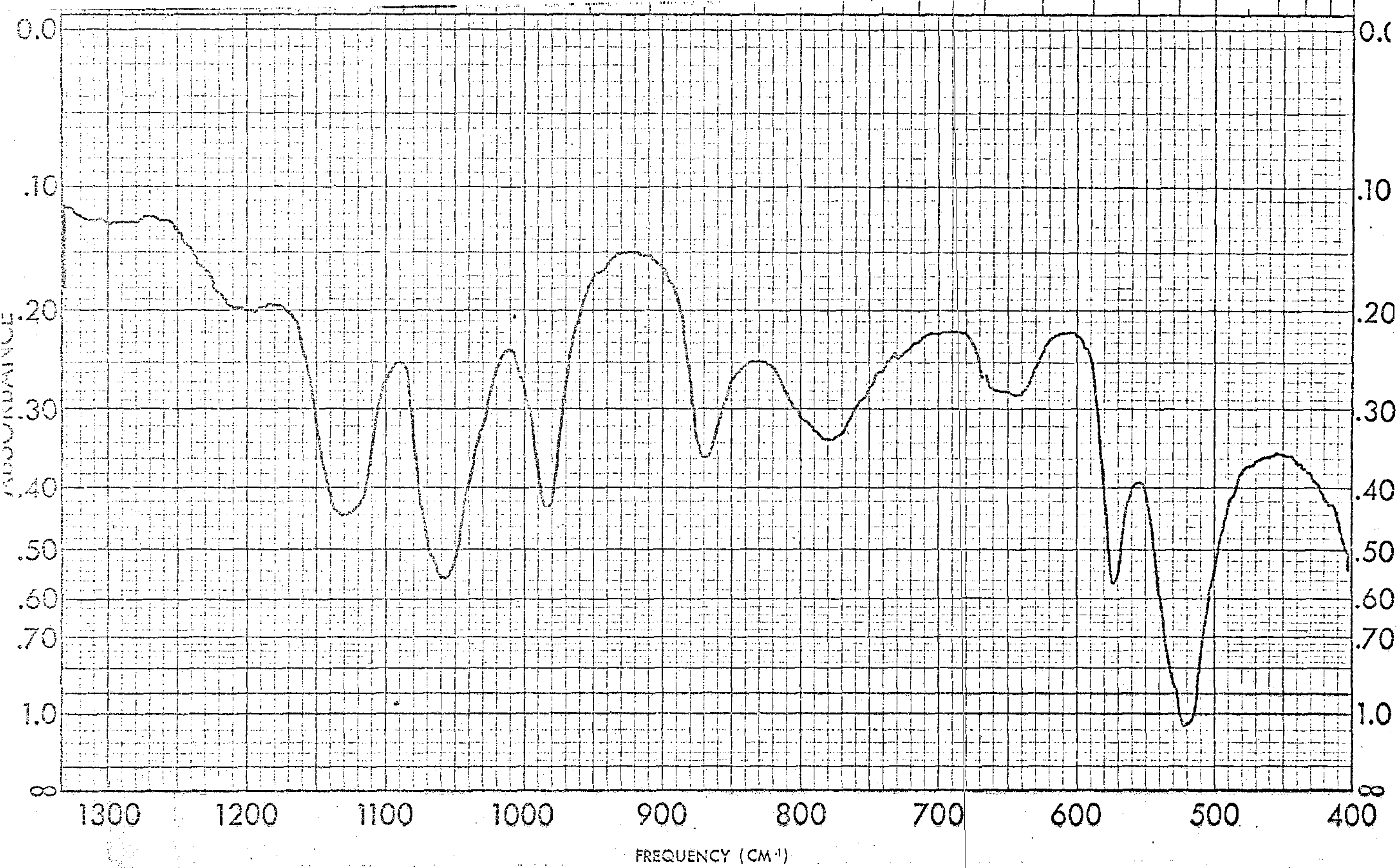
Spectrum No. 66: Magnesium Ammonium Phosphate, $MgNH_4PO_4$ by A.T.R.



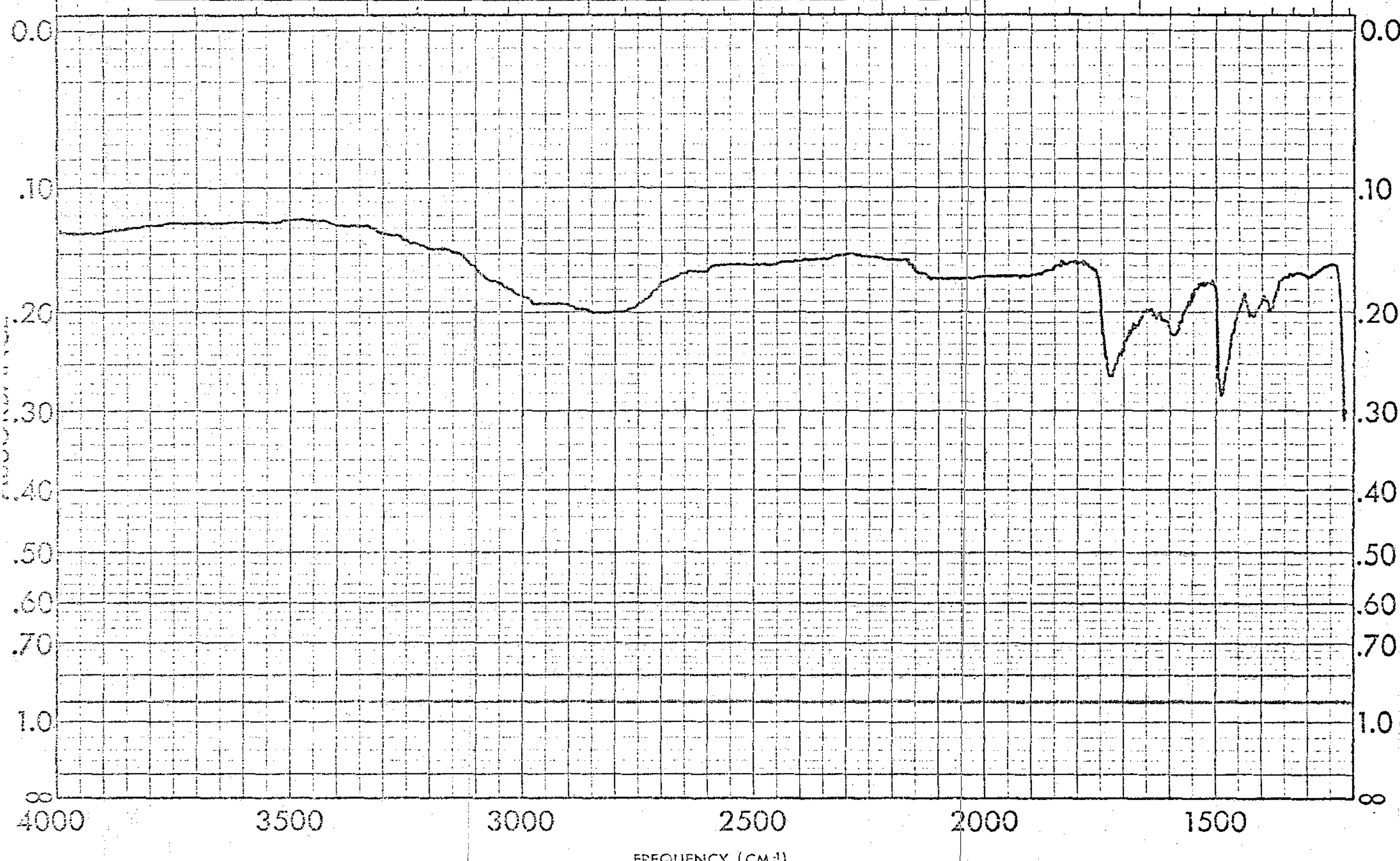
Spectrum No. 66: Magnesium Ammonium Phosphate, $MgNH_4PO_4$ by A.T.R.



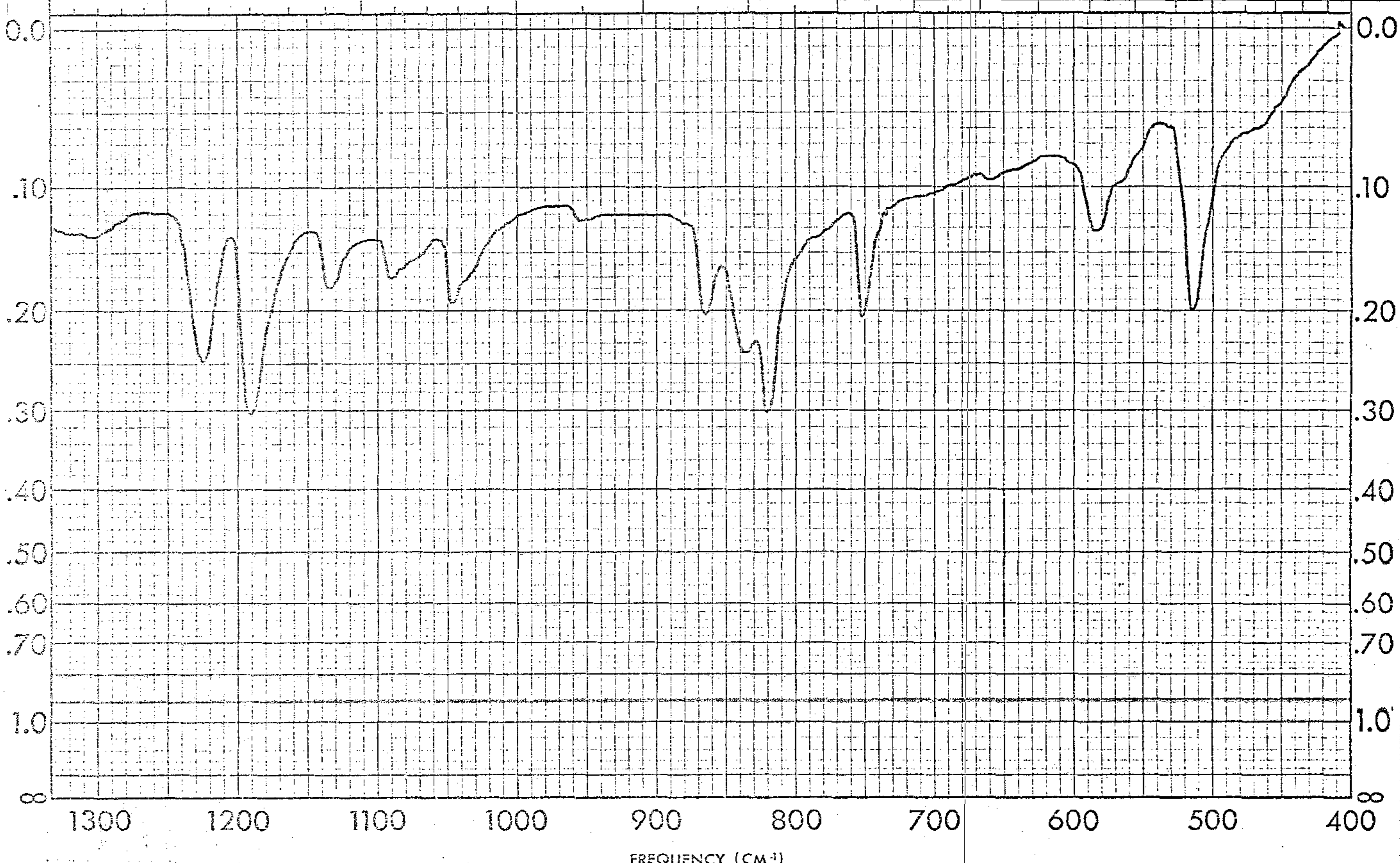
Spectrum No. 67: Calcium Hydrogen Phosphate, $CaHPO_4$ by A.T.R.



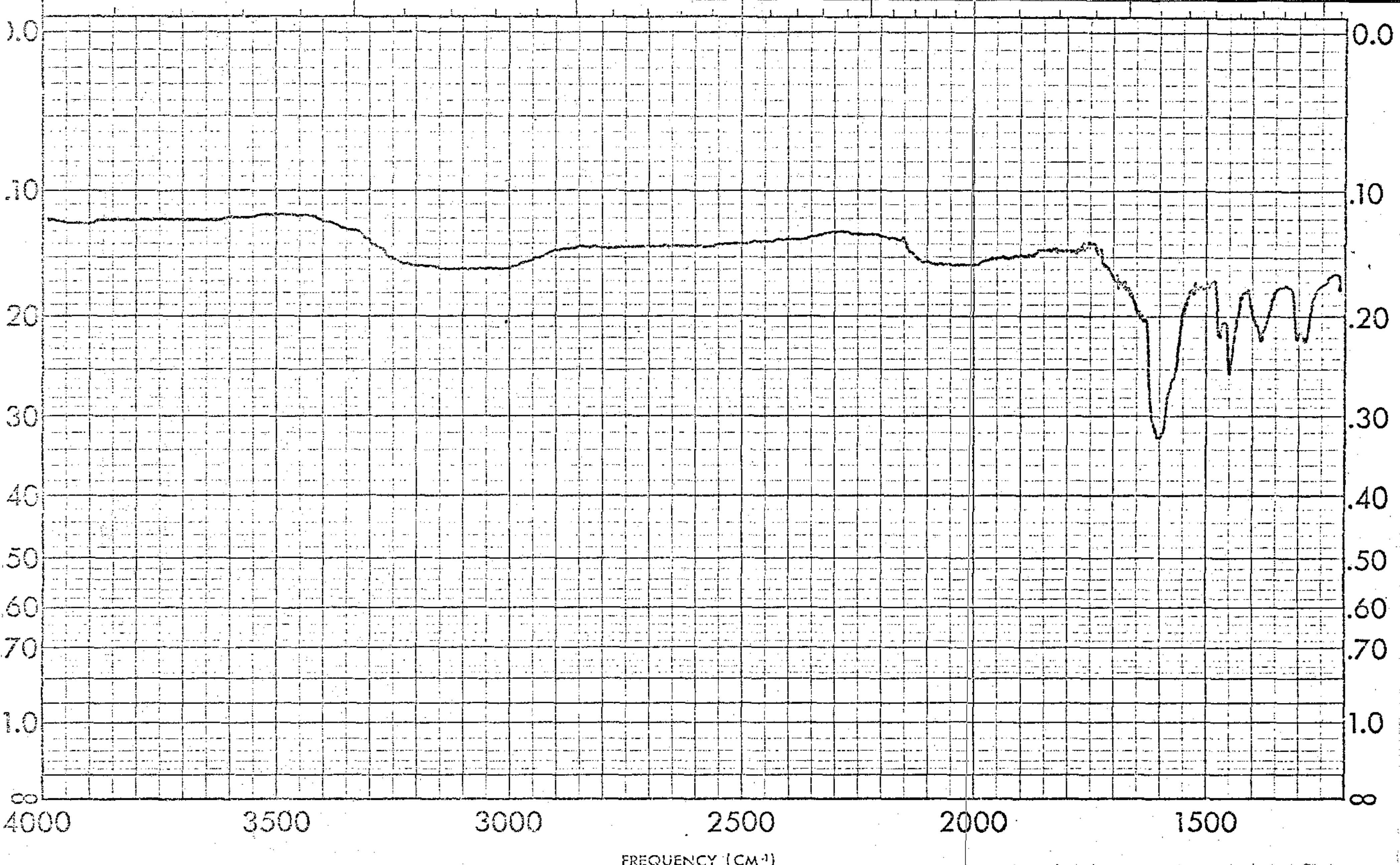
Spectrum No. 67: Calcium Hydrogen Phosphate, $CaHPO_4$ by A.T.R.



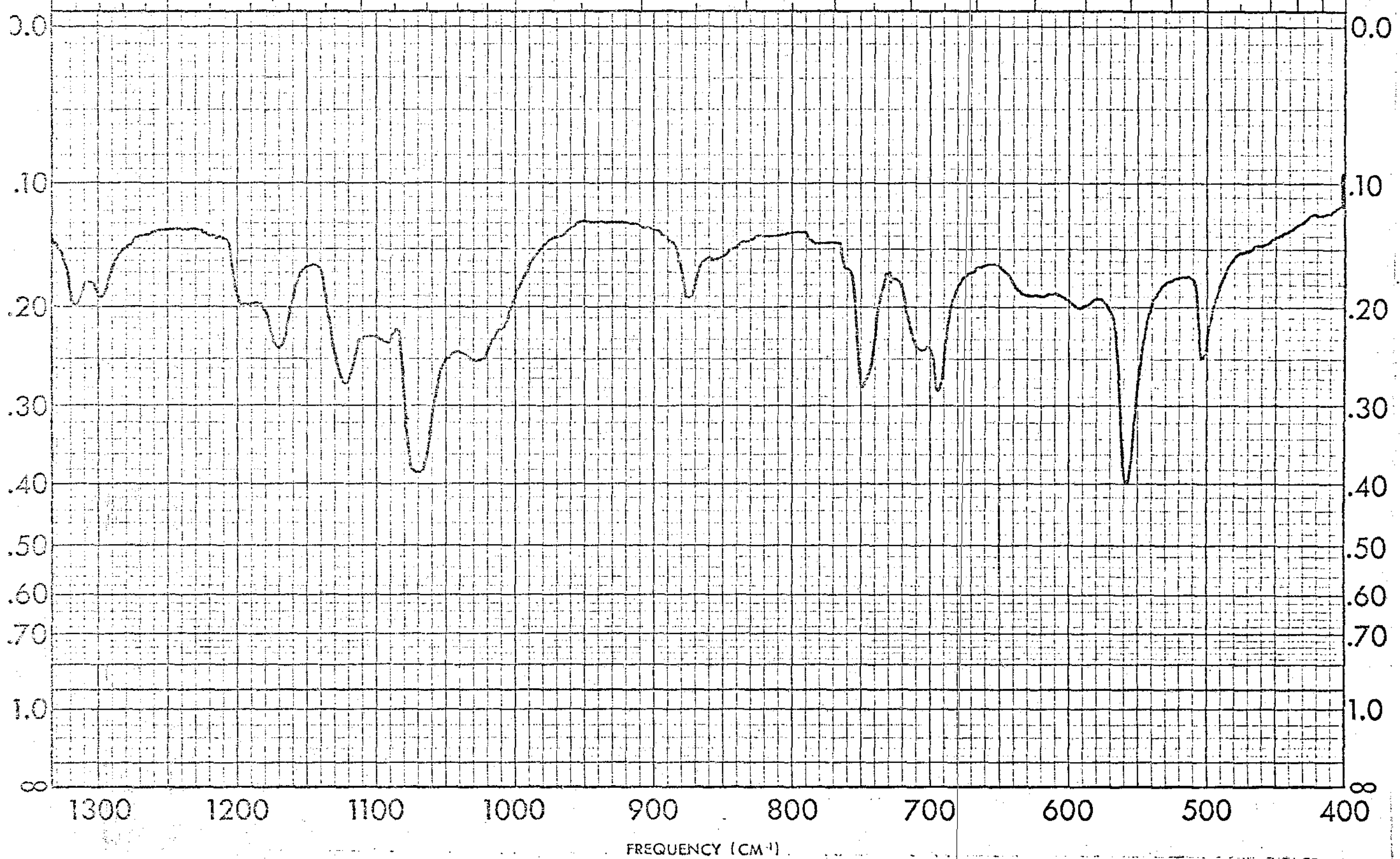
Spectrum No. 68: Cystine, $SCH_2CH(NH_2)-COOH$ by A.T.R.



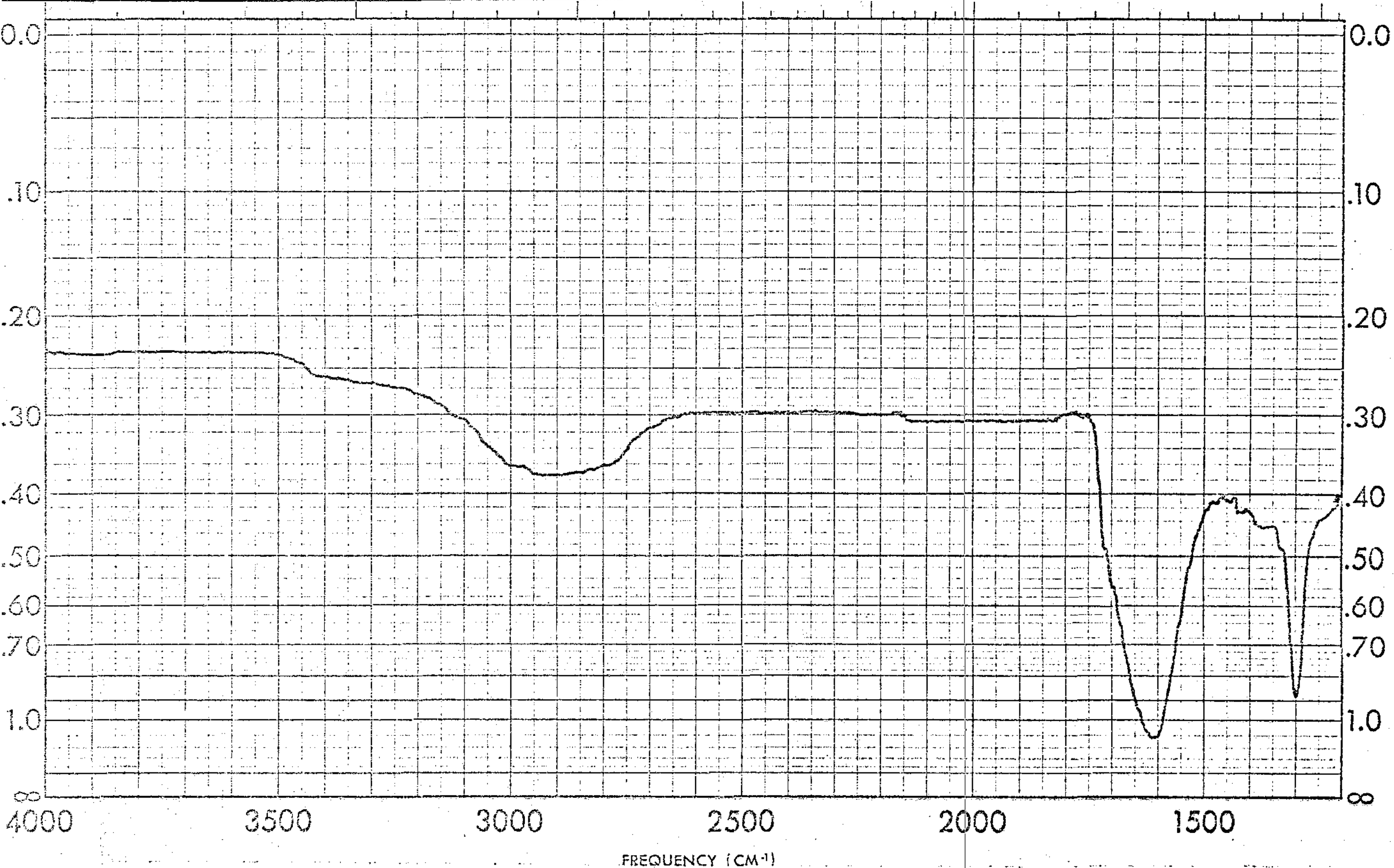
Spectrum No. 68: Cystine, $SCH_2CH(NH_2)$-COOH by A.T.R.



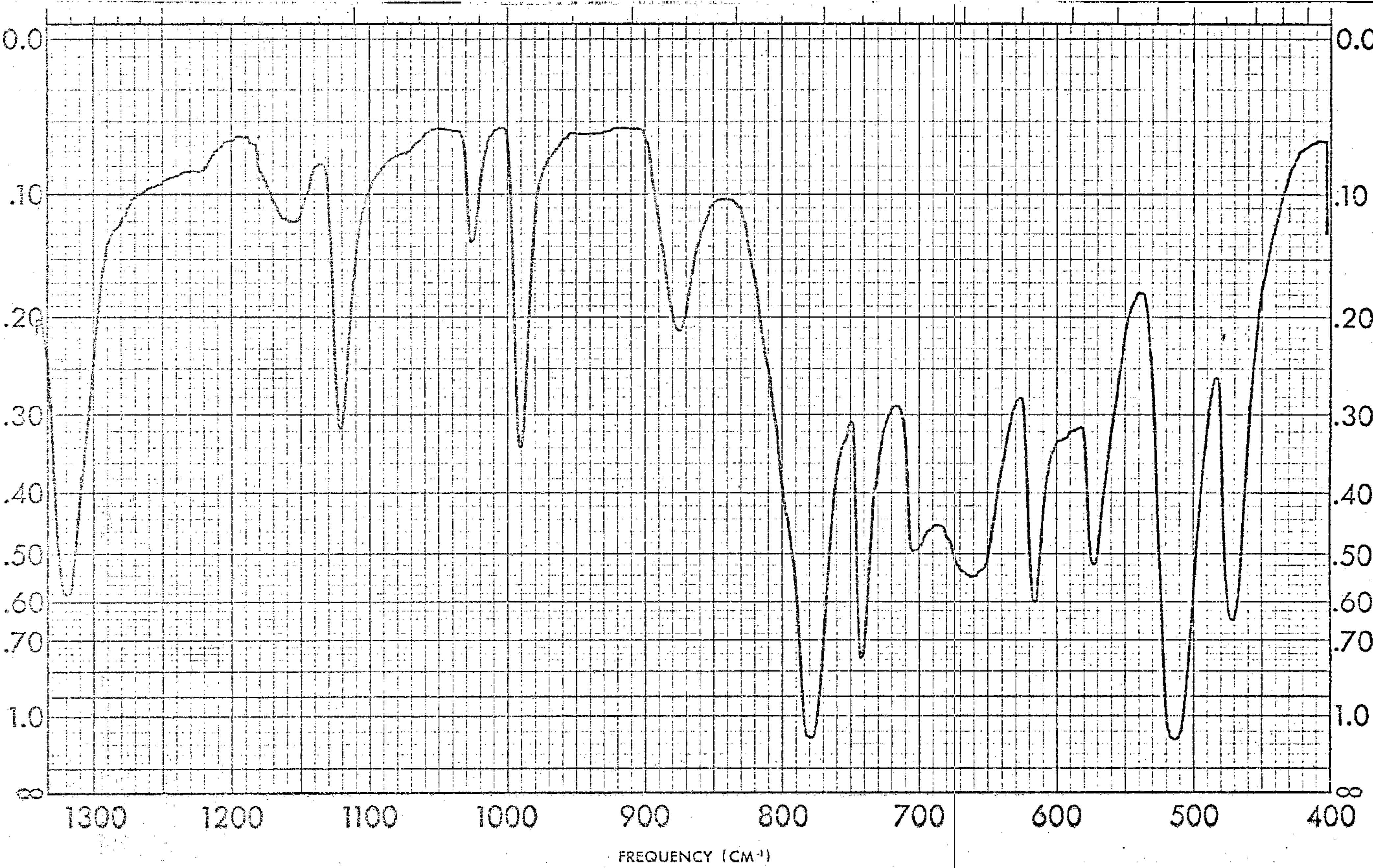
Spectrum No. 69: Indigo, $C_{16}H_{10}N_2O_2$ by A.T.R.



Spectrum No. 69: Indigo, $C_{16}H_{10}N_2O_2$ by A.T.R.

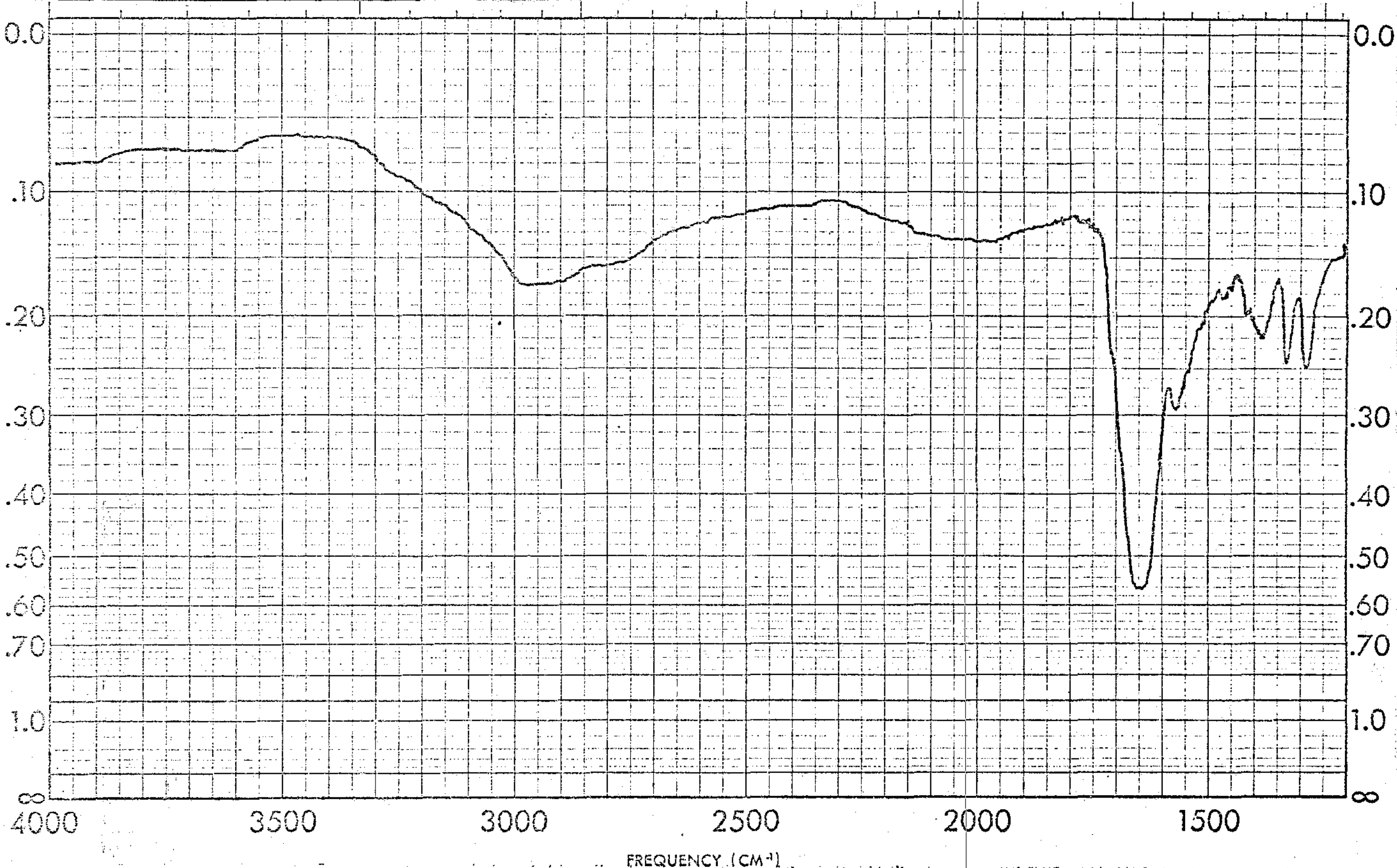


Spectrum No. 70: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ by A.T.R.

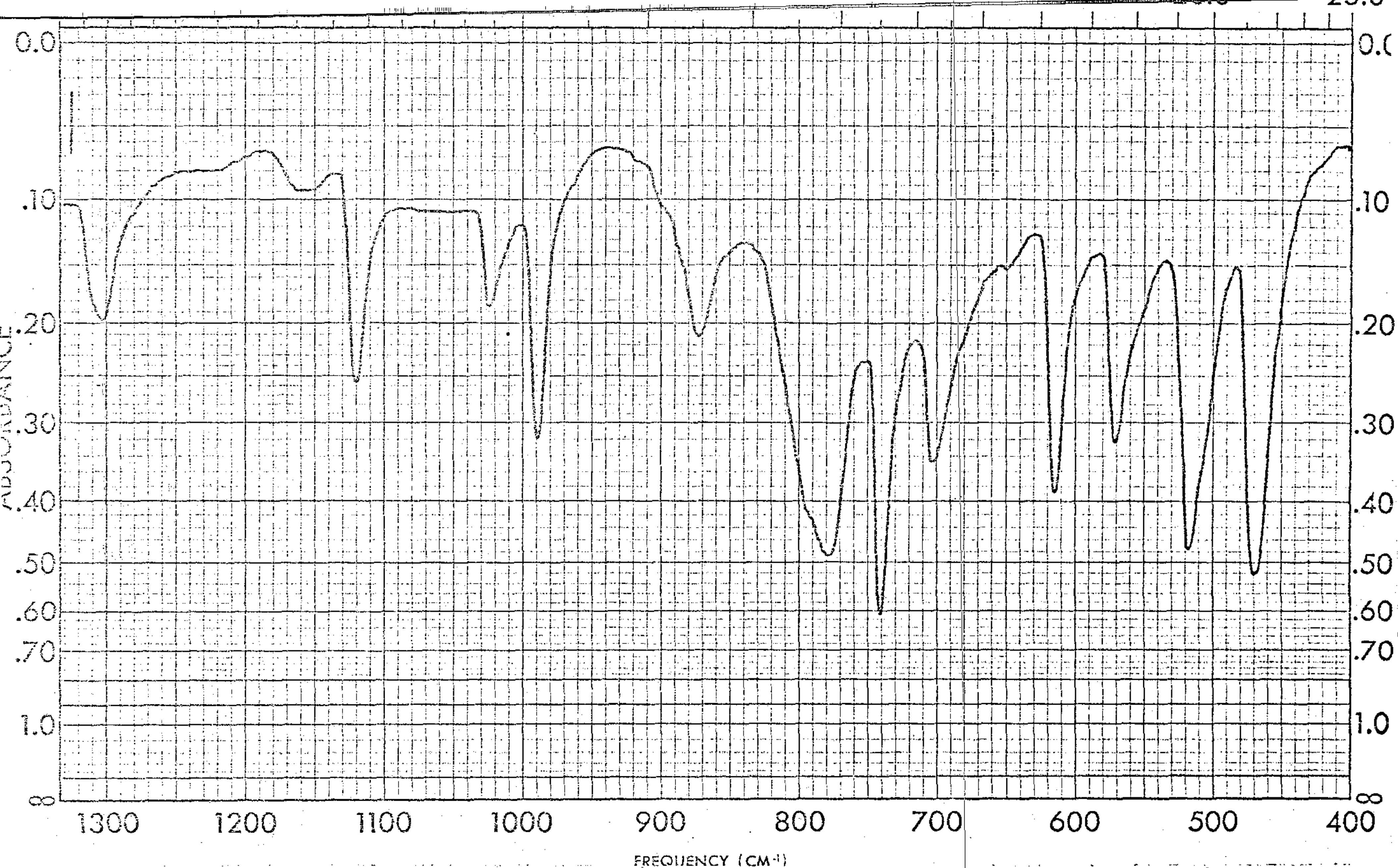


Spectrum No. 70: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Calcium Oxalate

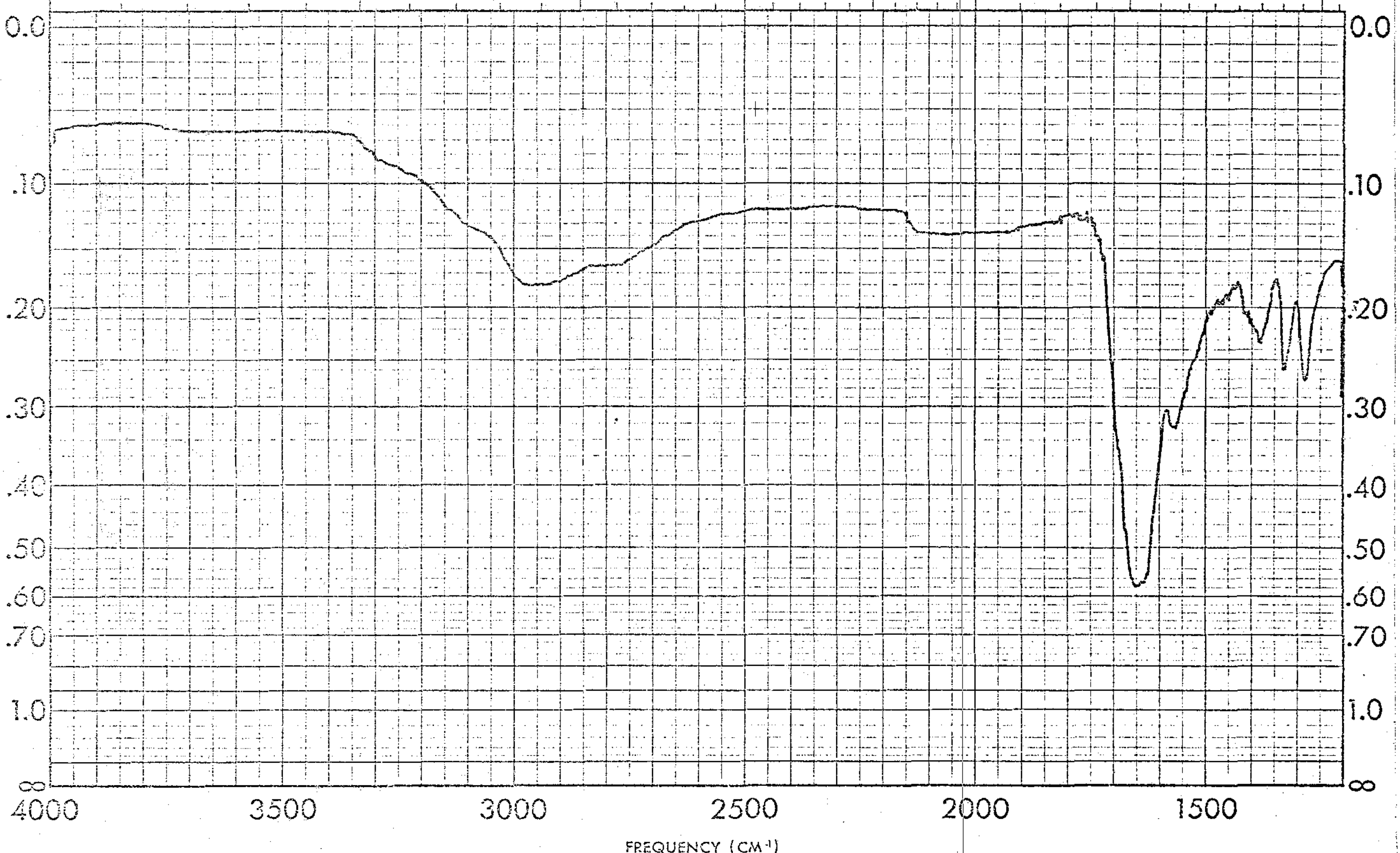
Monohydrate, $CaC_2O_4 \cdot H_2O$ by A.T.R.



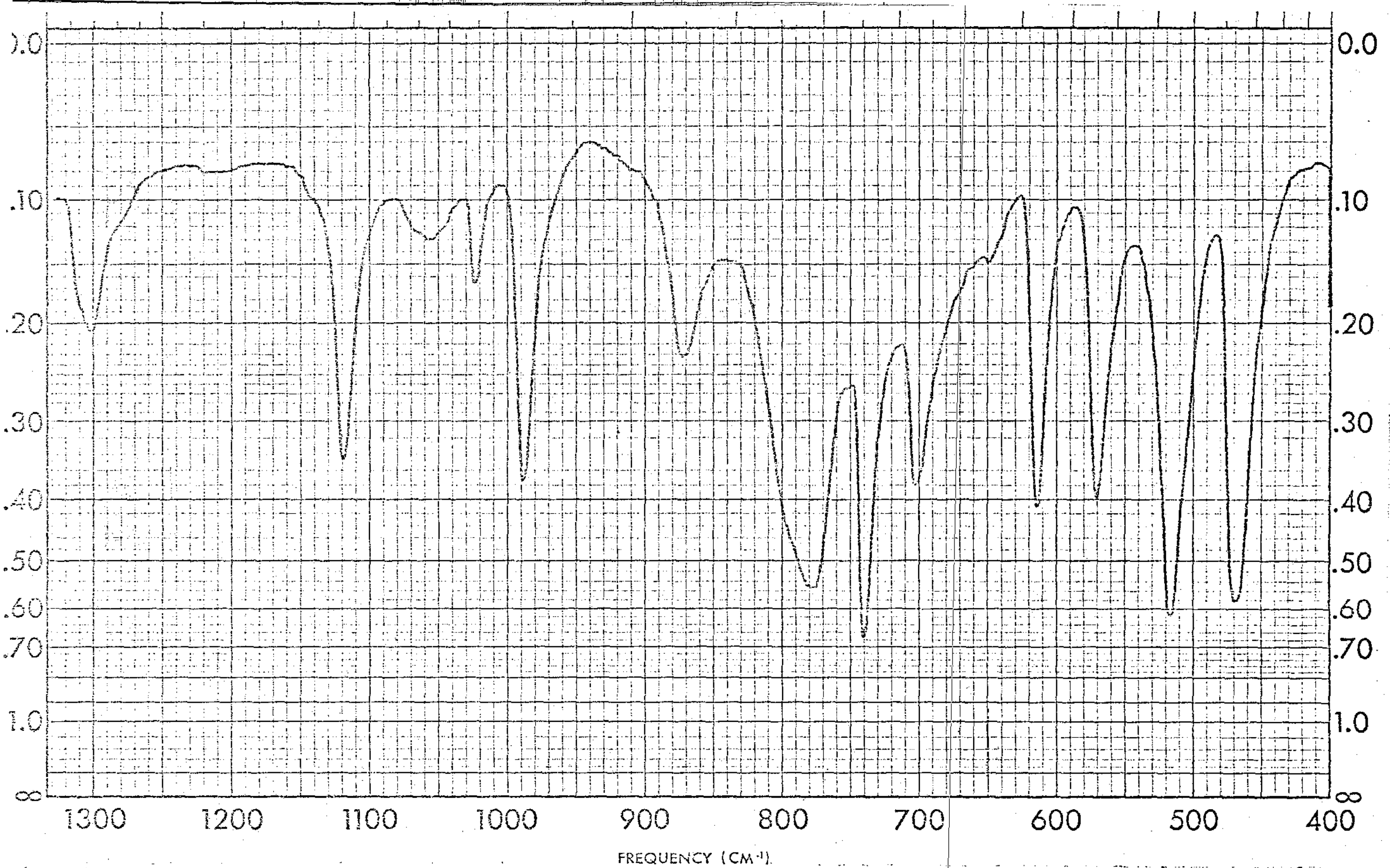
Spectrum No. 71: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



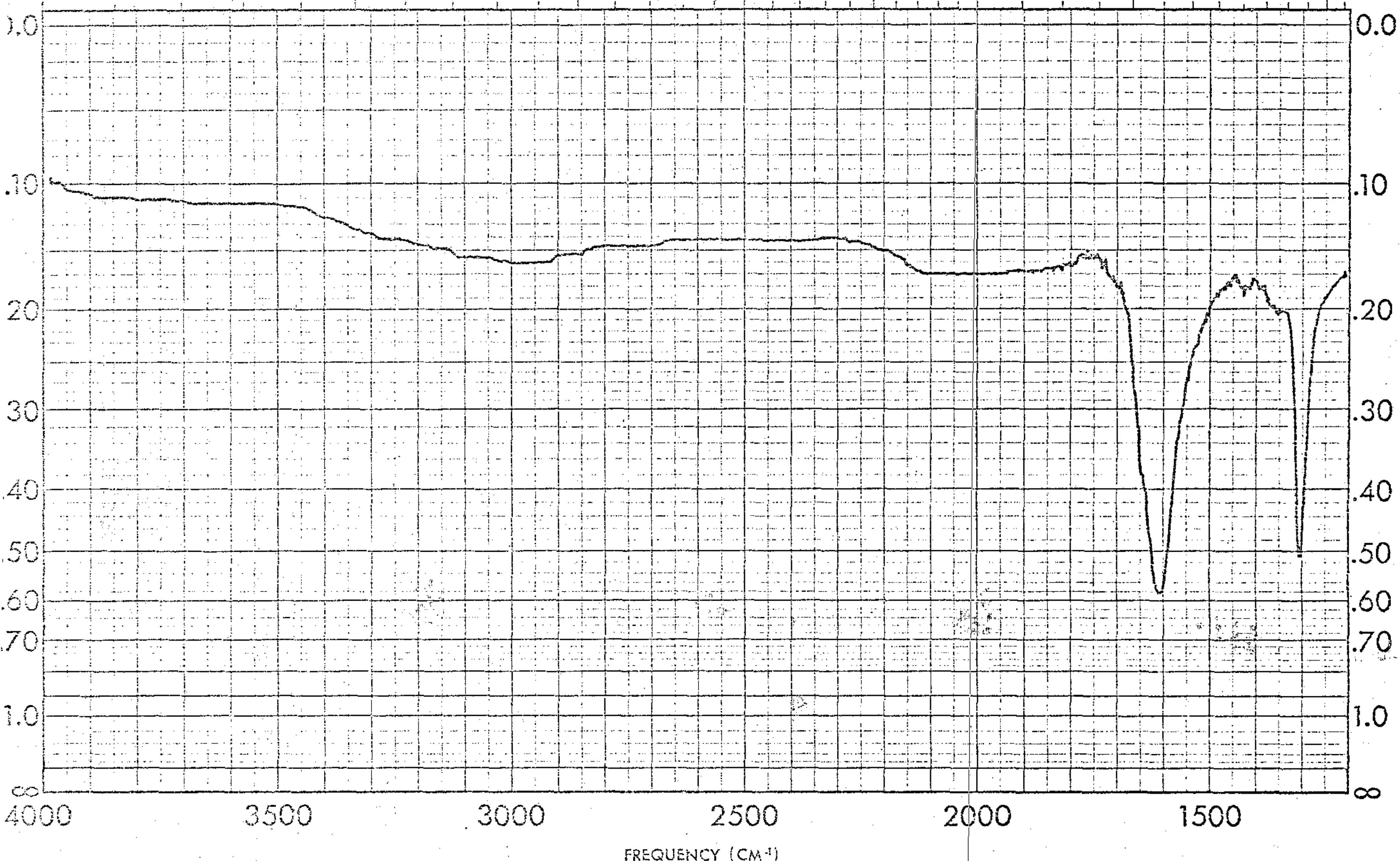
Spectrum No. 71: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



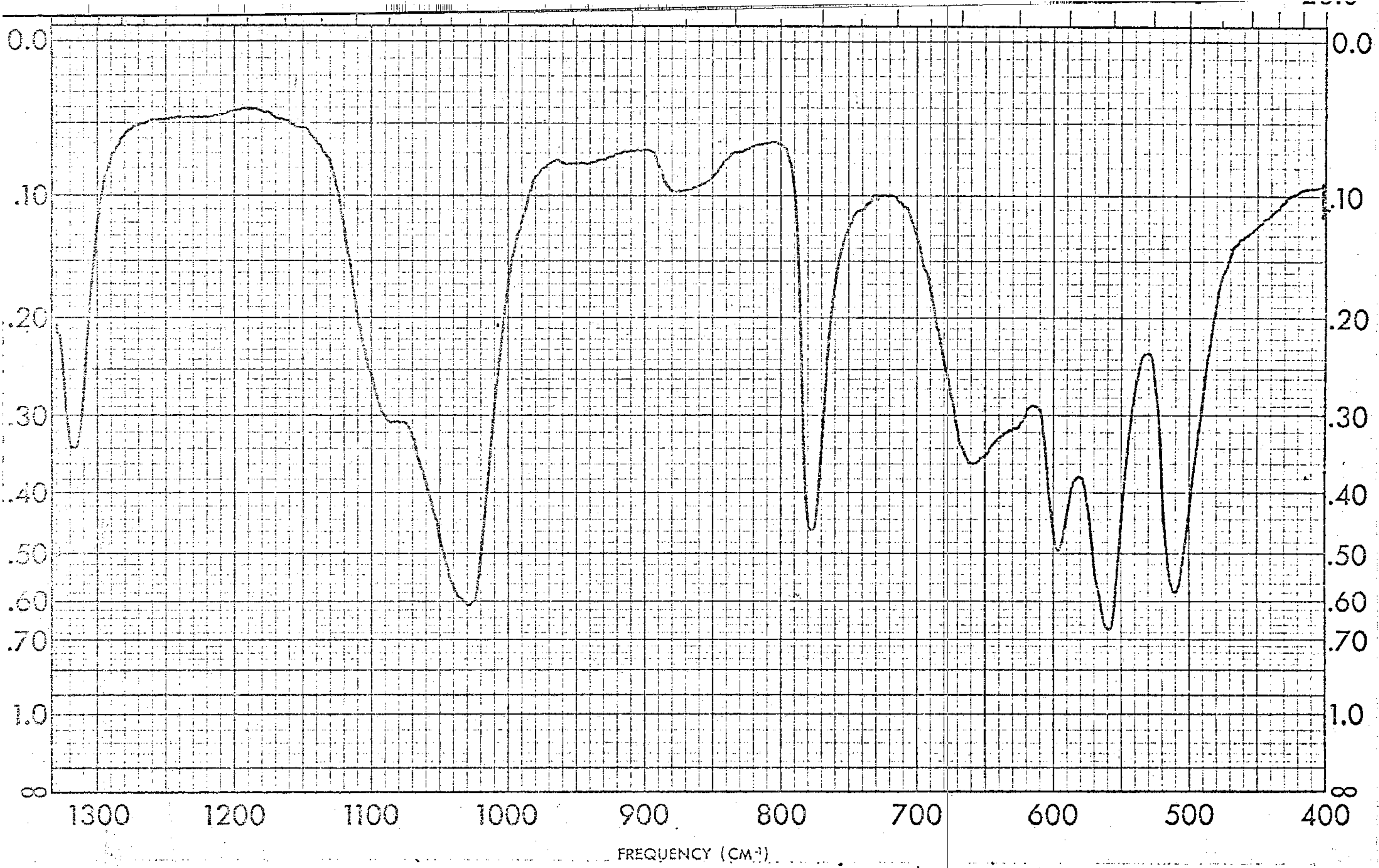
Spectrum No. 72: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ by A.T.R.



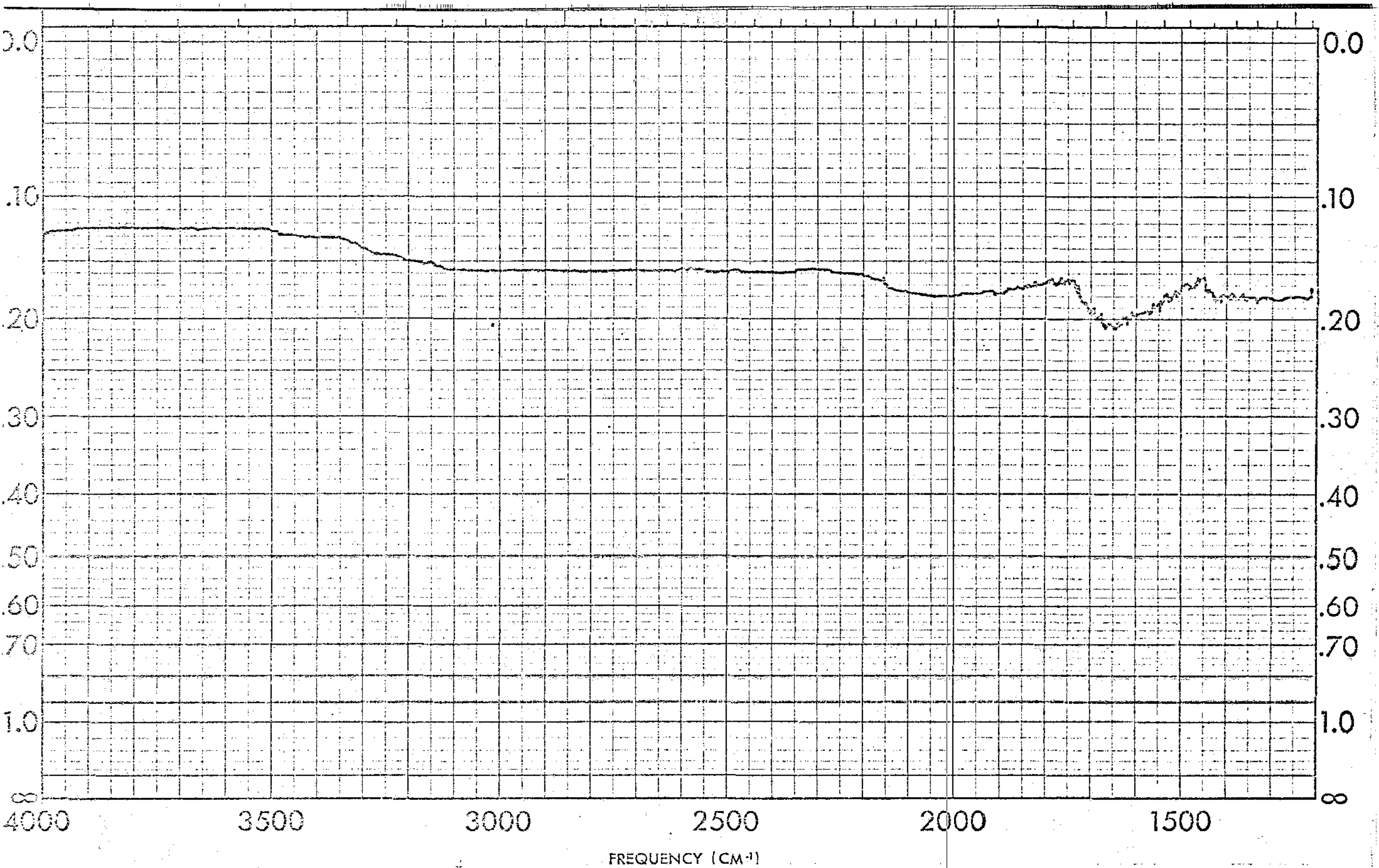
Spectrum No. 72: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ by A.T.R.



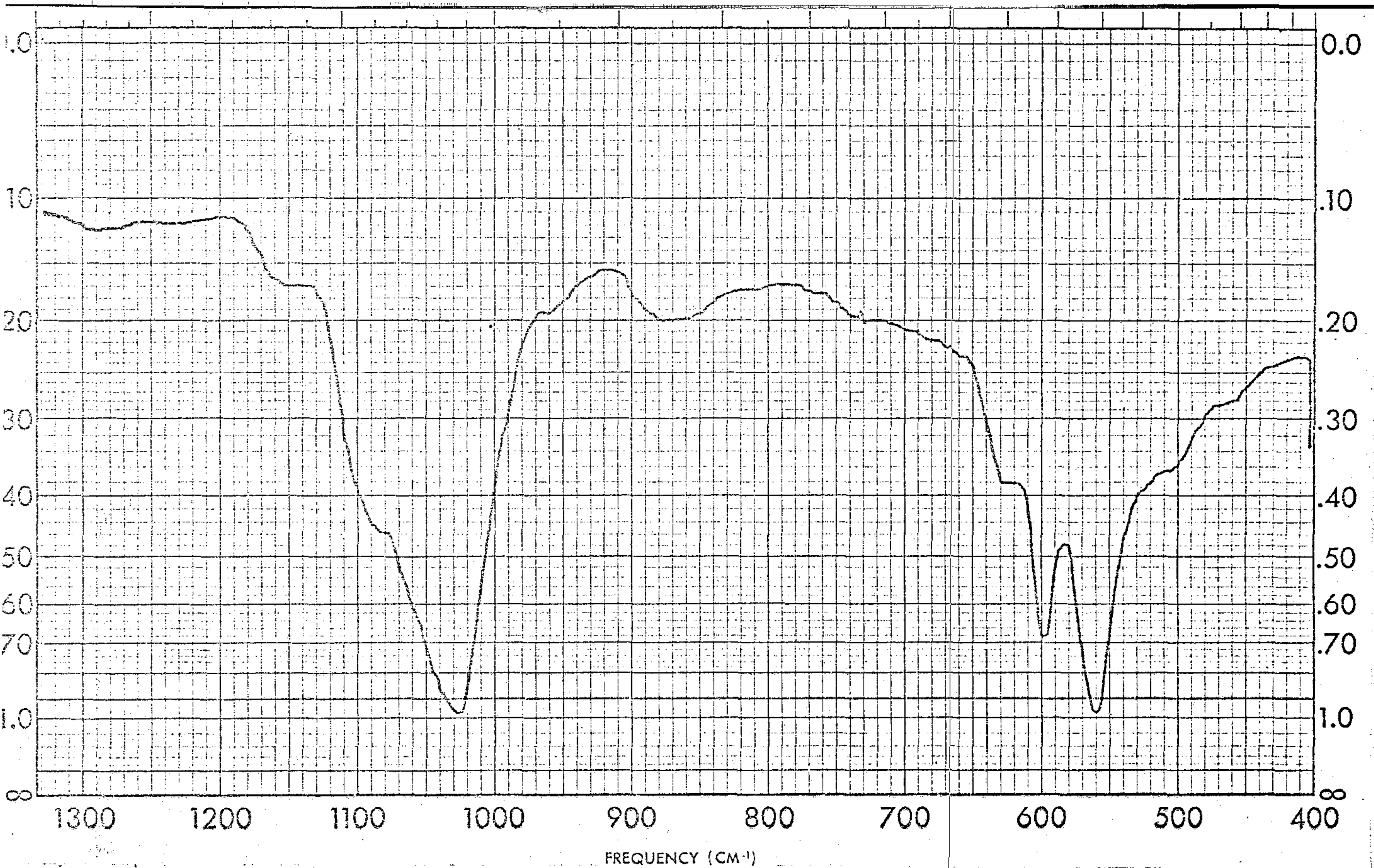
Spectrum No. 73: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50% Calcium Oxalate Monohydrate $CaC_2O_4.H_2O$ by A.T.R.



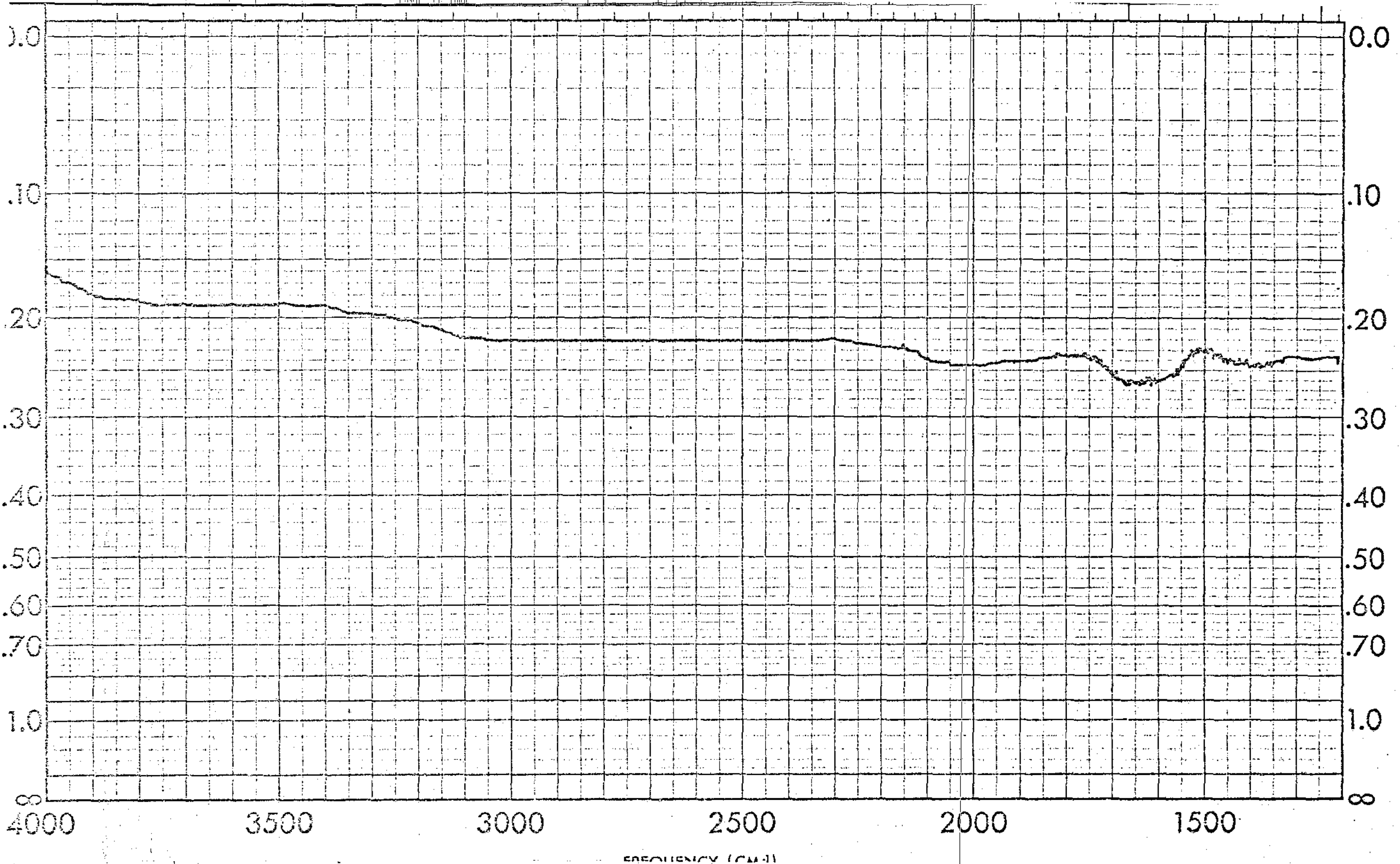
Spectrum No. 73: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ by A.T.R.



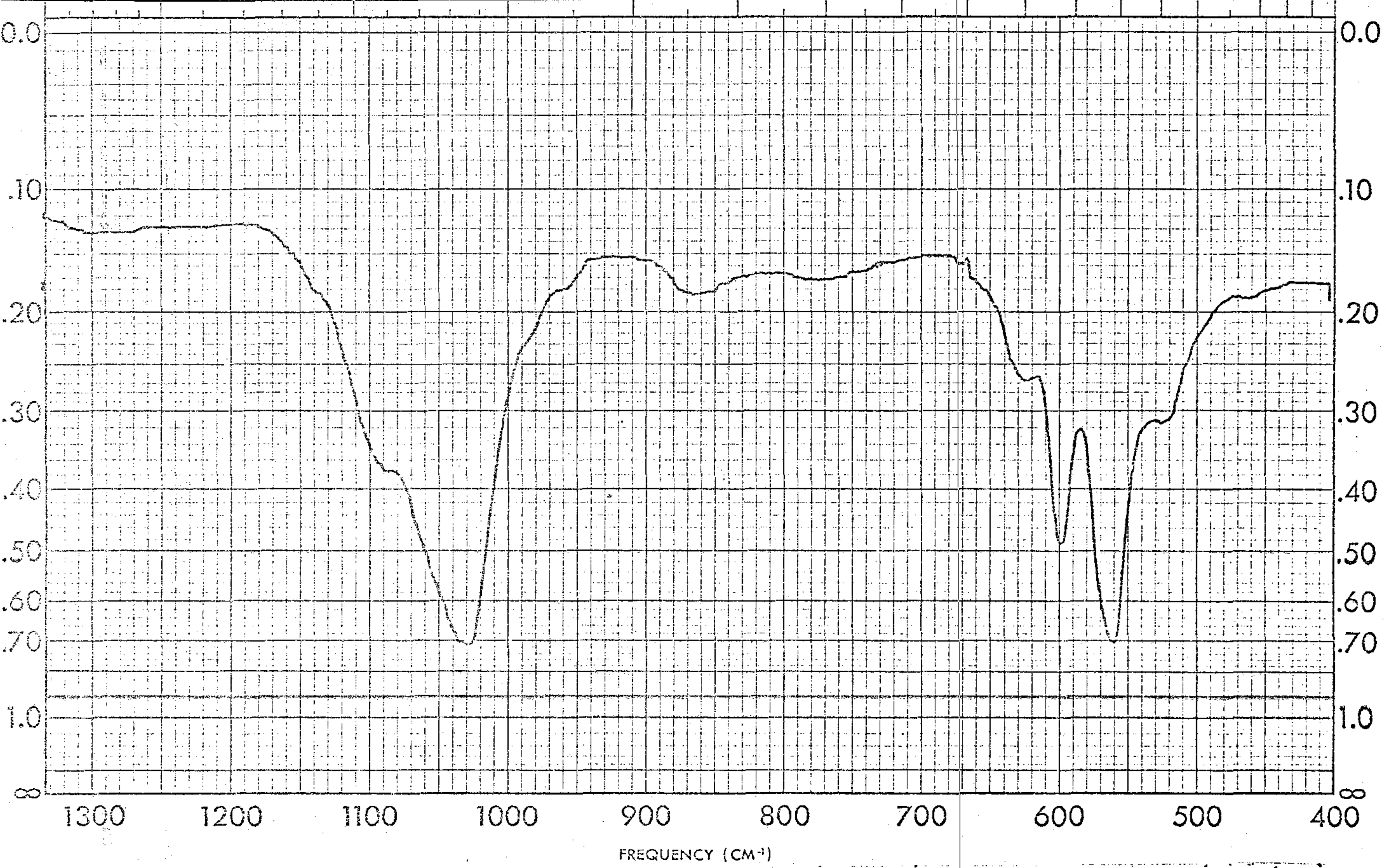
Spectrum No. 74: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



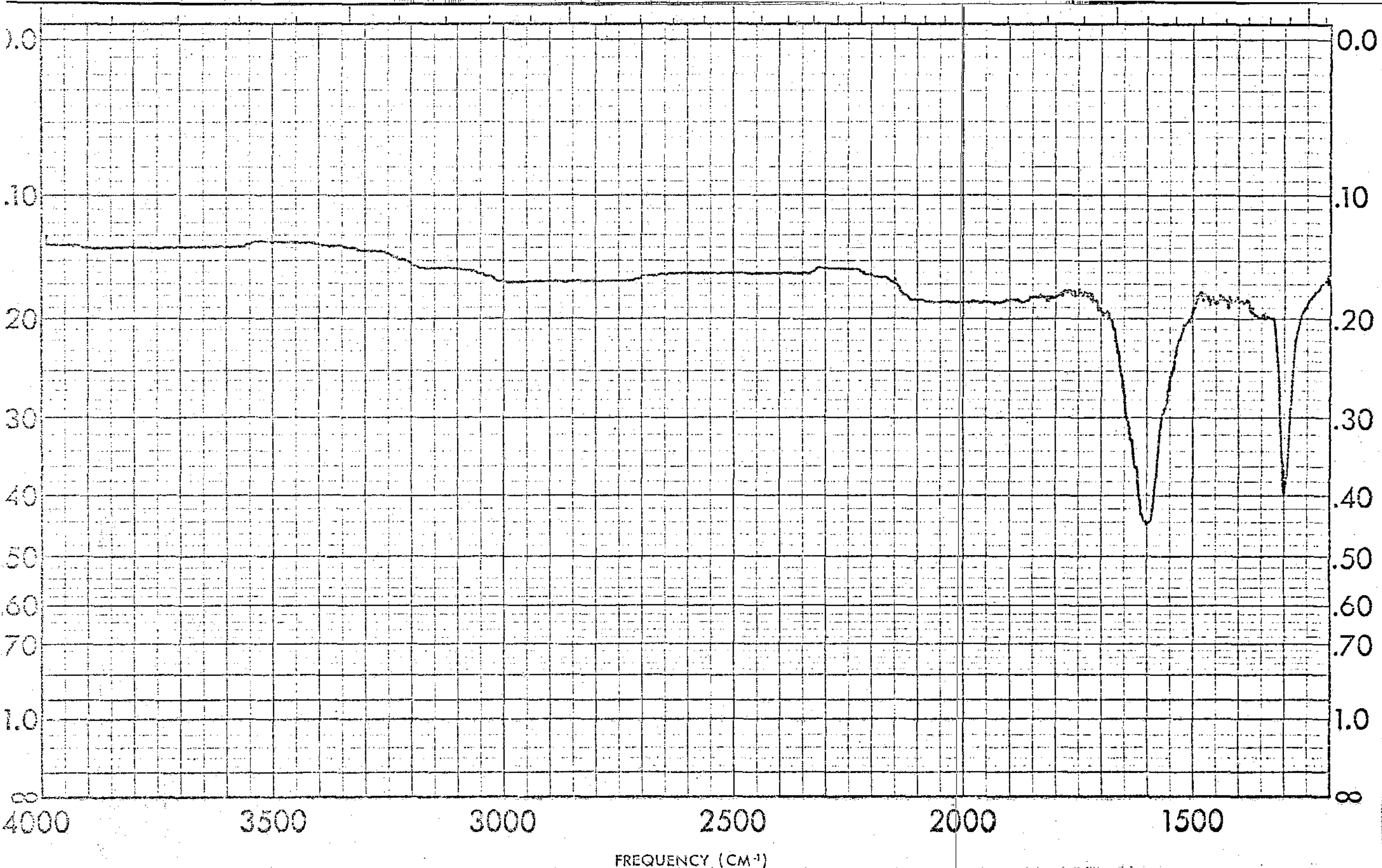
Spectrum No. 74: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



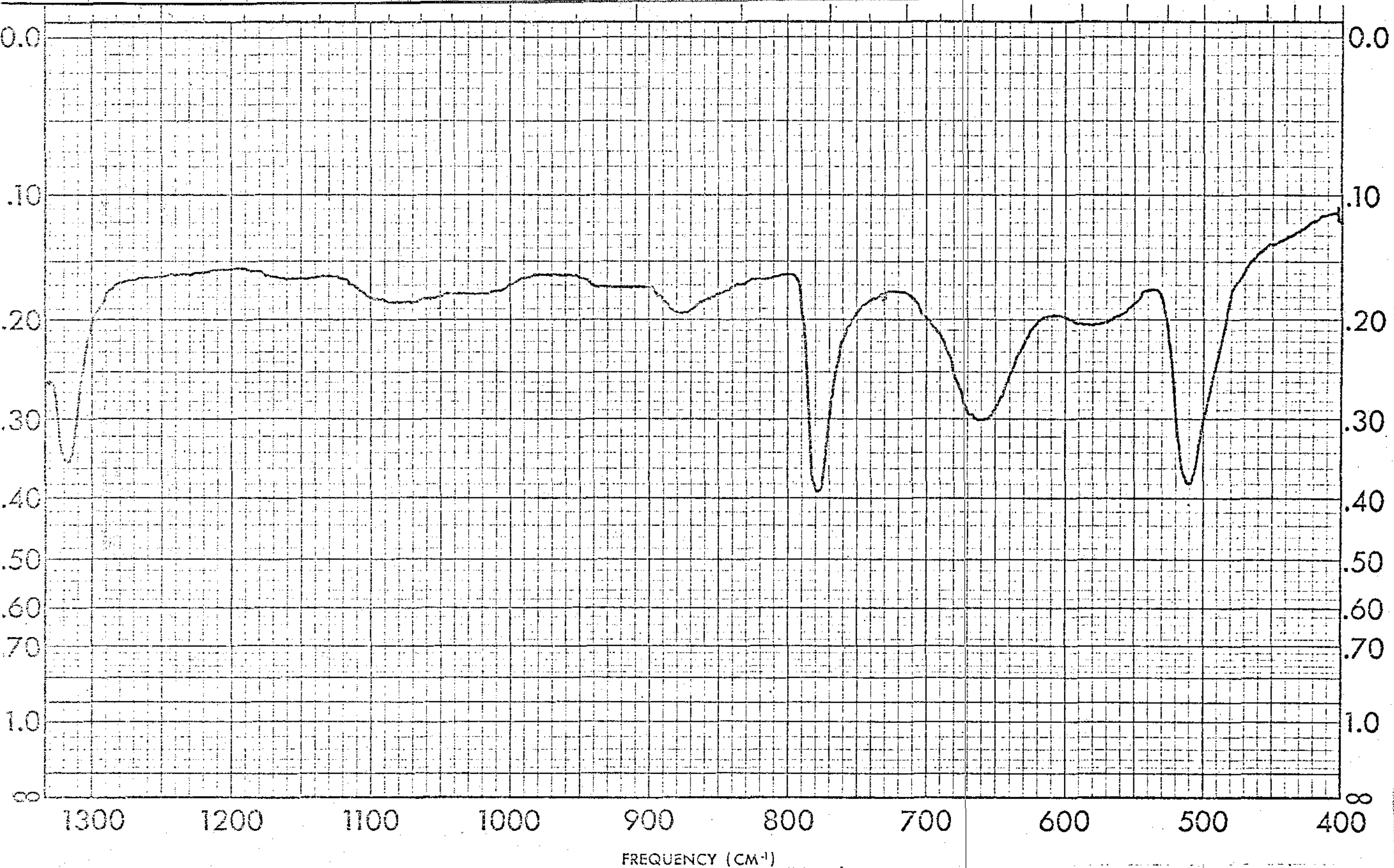
Spectrum No. 75: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ by A.T.R.



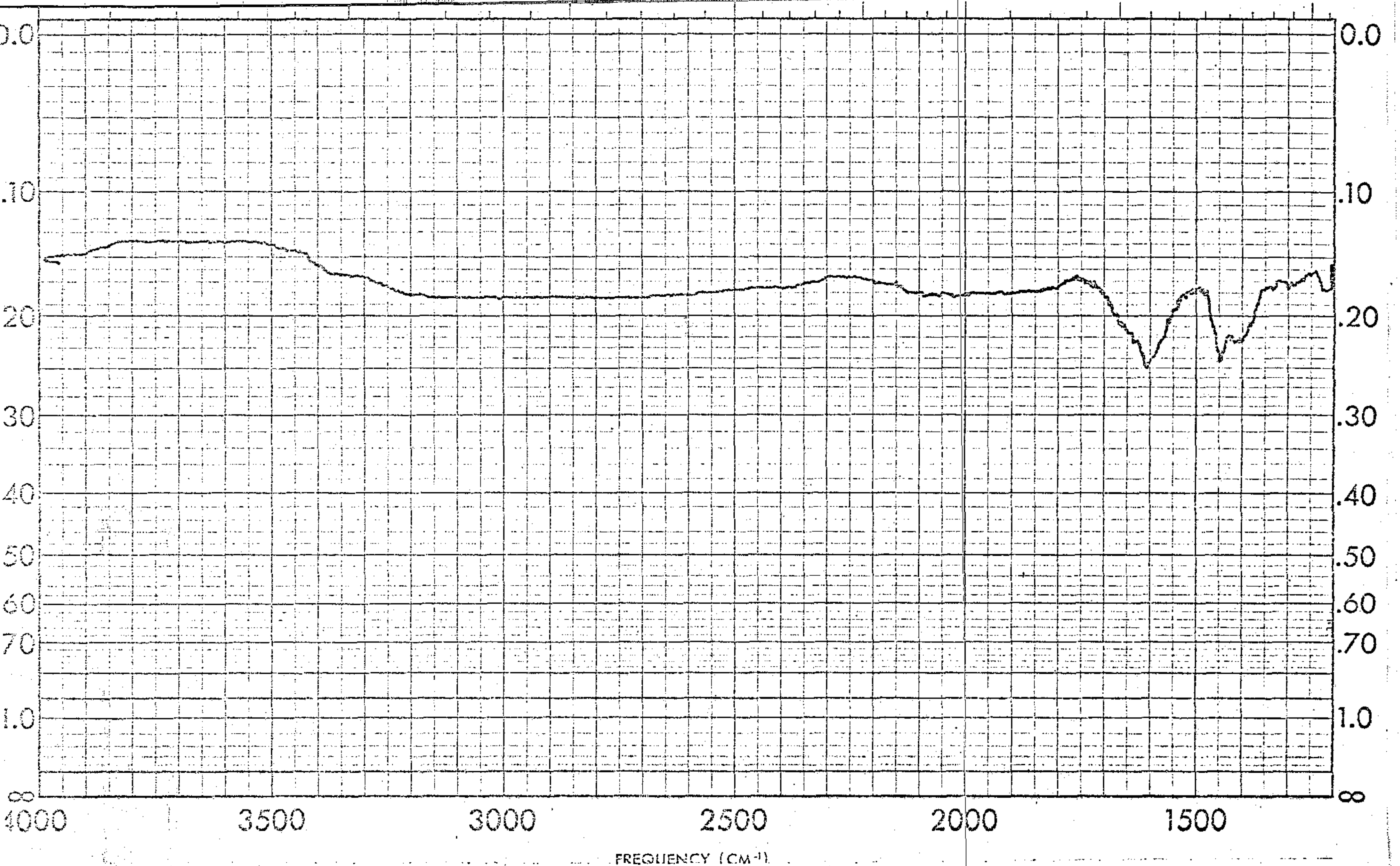
Spectrum No. 75: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ by A.T.R.



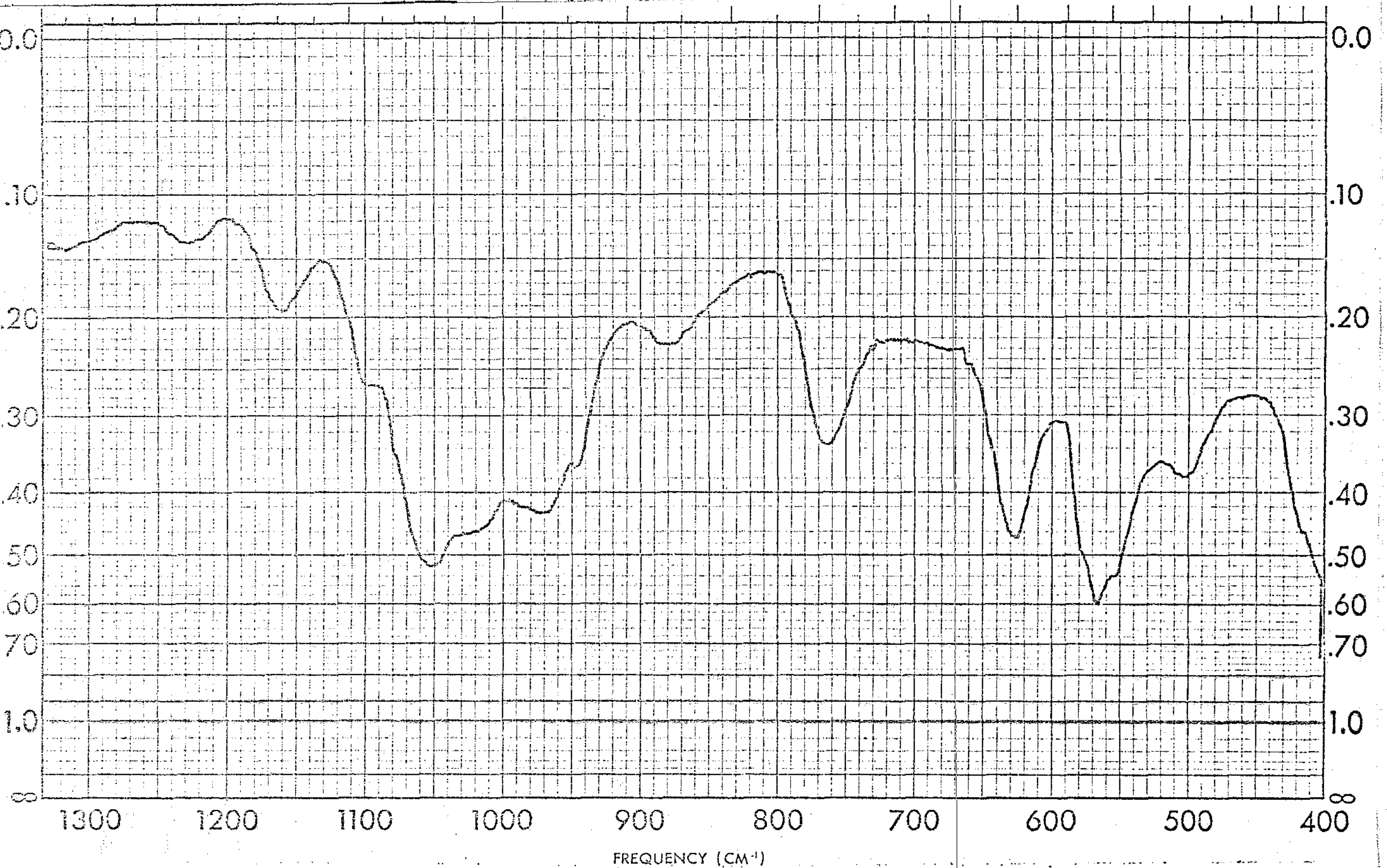
Spectrum No. 76: 50% Magnesium Ammonium Phosphate, $MgHPO_4$, and 50% Calcium Oxalate Monohydrate $CaC_2O_4 \cdot H_2O$ by A.T.R.



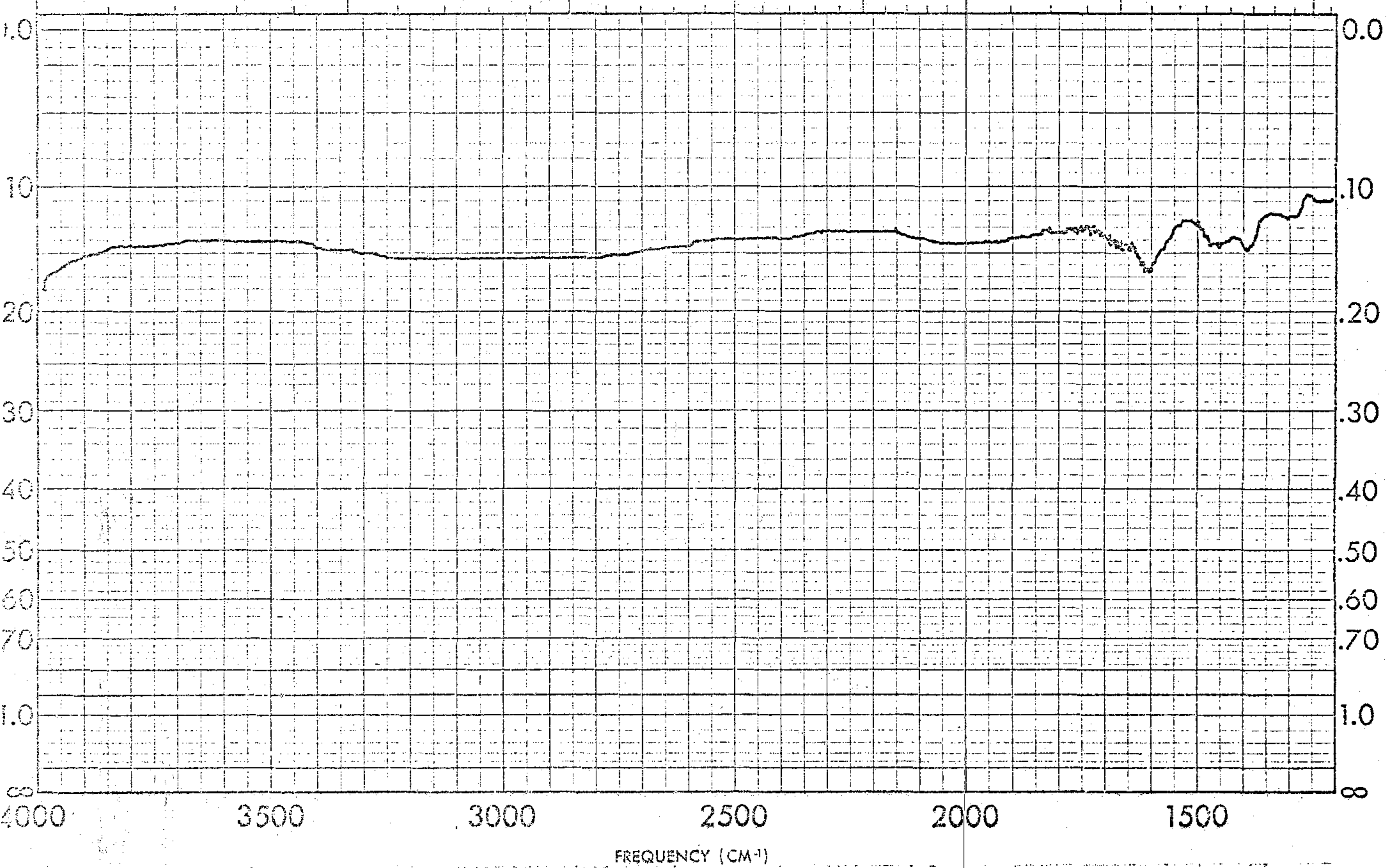
Spectrum No. 76: 50% Magnesium Ammonium Phosphate, $MgHPO_4$, and 50% Calcium Oxalate Monohydrate $CaC_2O_4 \cdot H_2O$ by A.T.R.



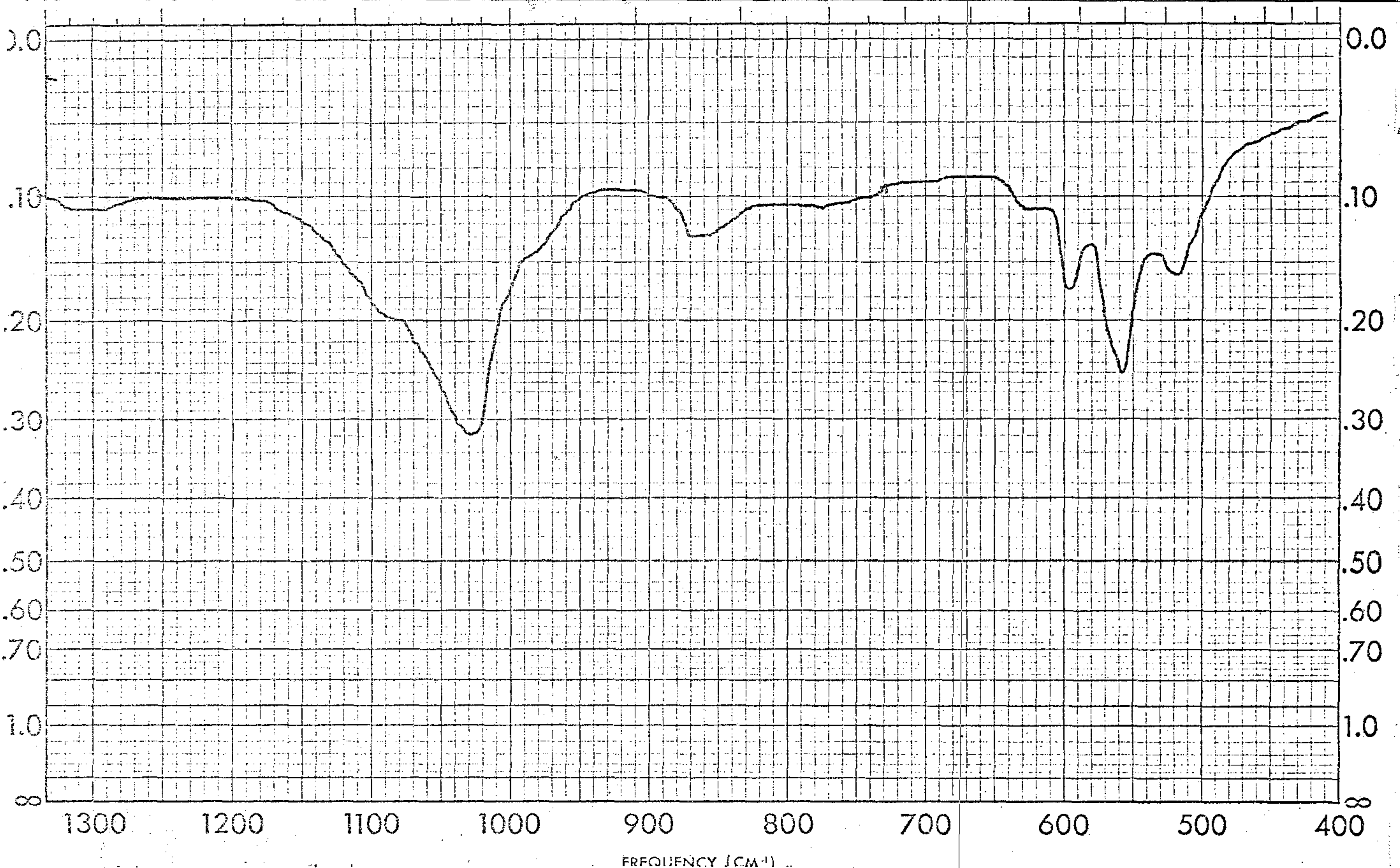
Spectrum No. 77: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 50% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



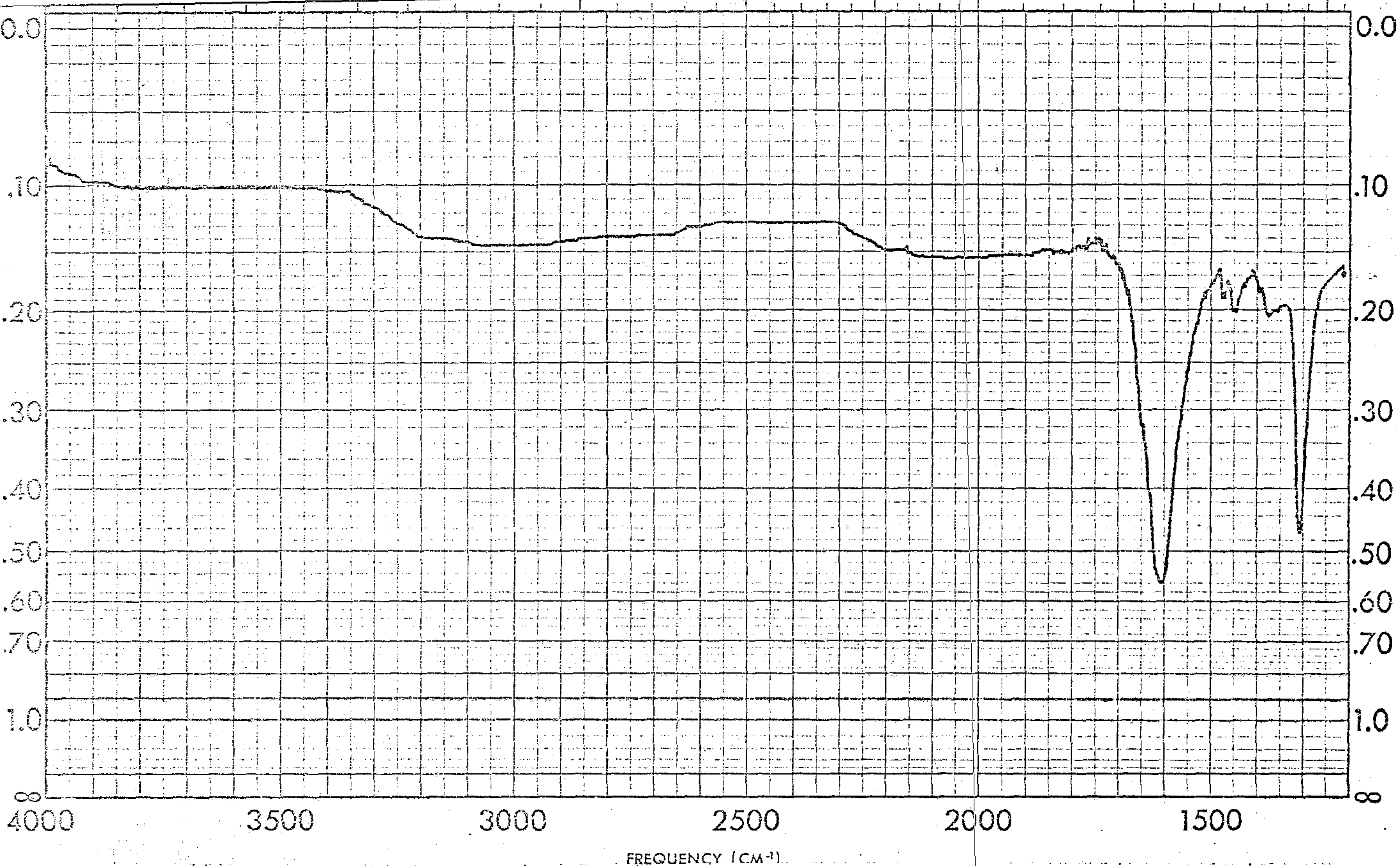
Spectrum No. 77: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 50% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



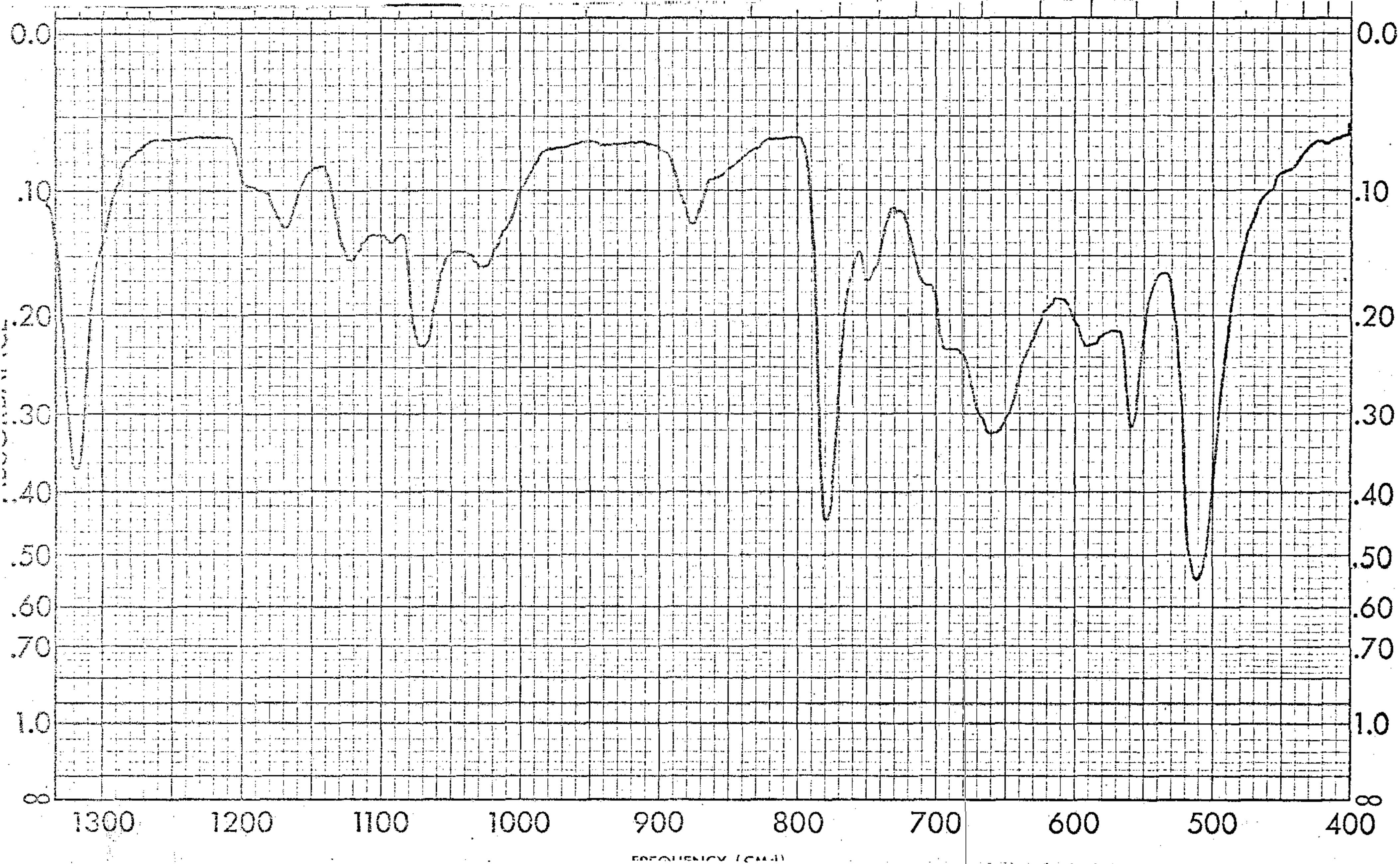
Spectrum No. 78: 50% Magnesium Phosphate, $MgHPO_4$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ by A.T.R.



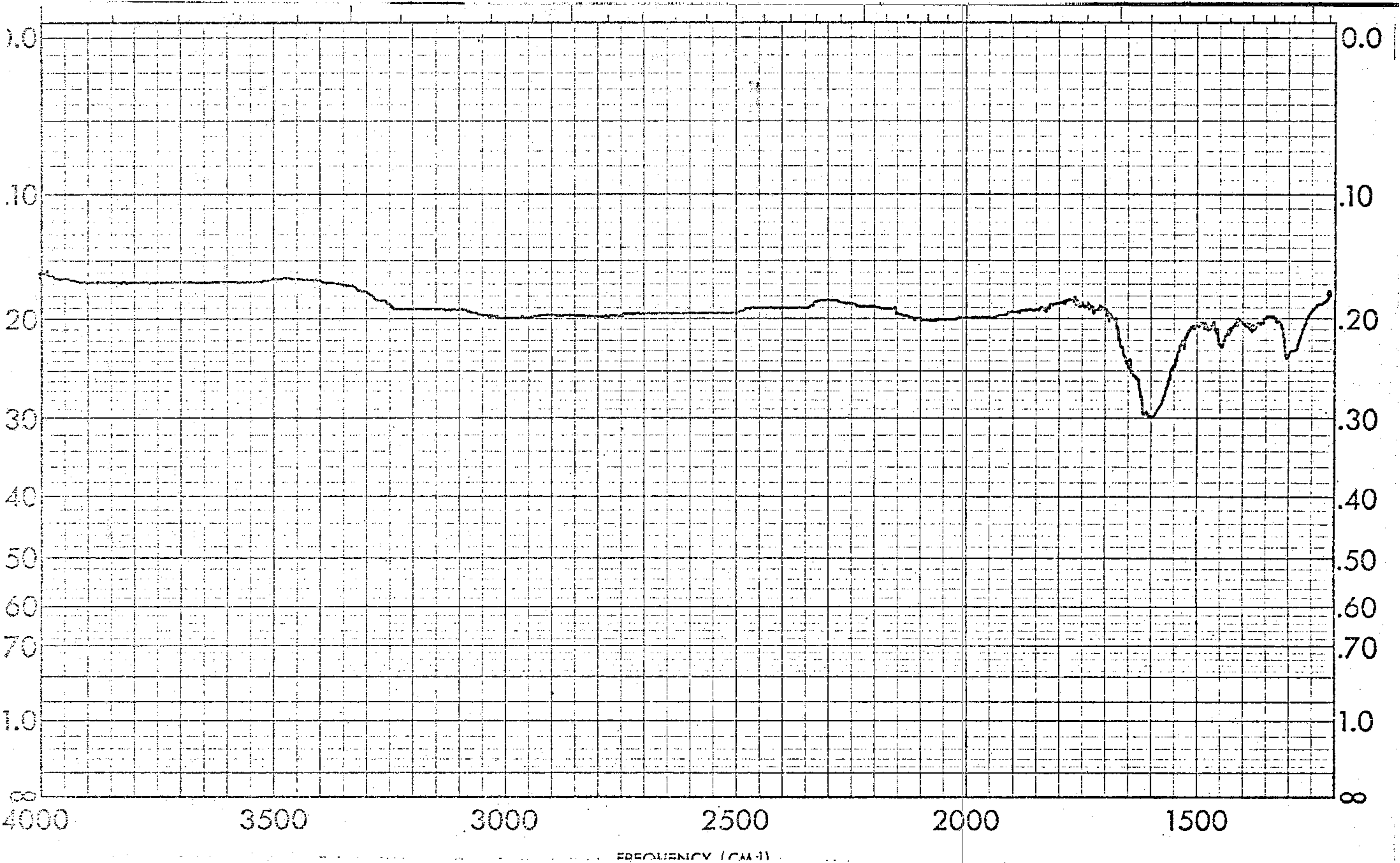
Spectrum No. 78: 50% Magnesium Phosphate, $MgHPO_4$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ by A.T.R.



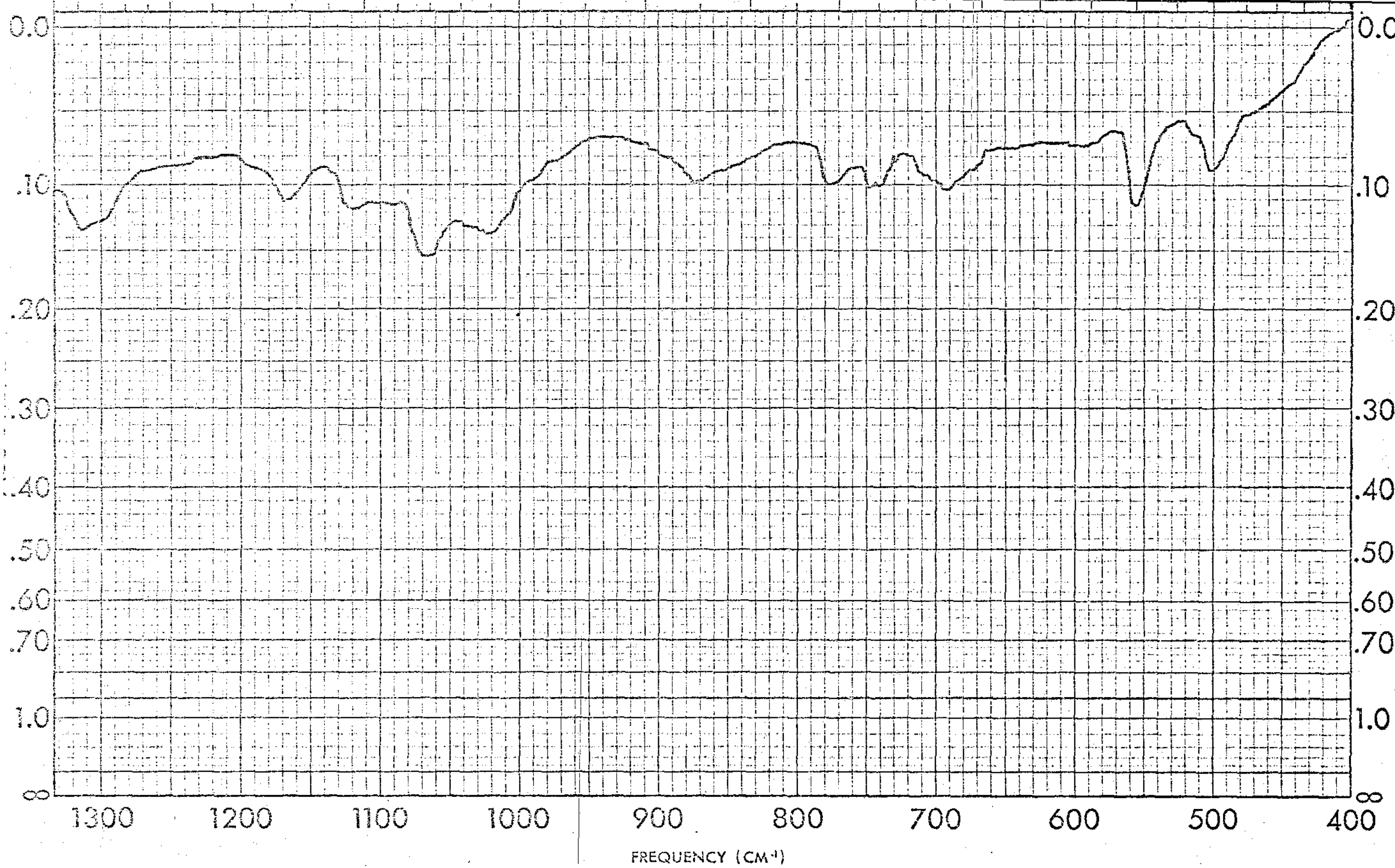
Spectrum No. 79: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ by A.T.R.



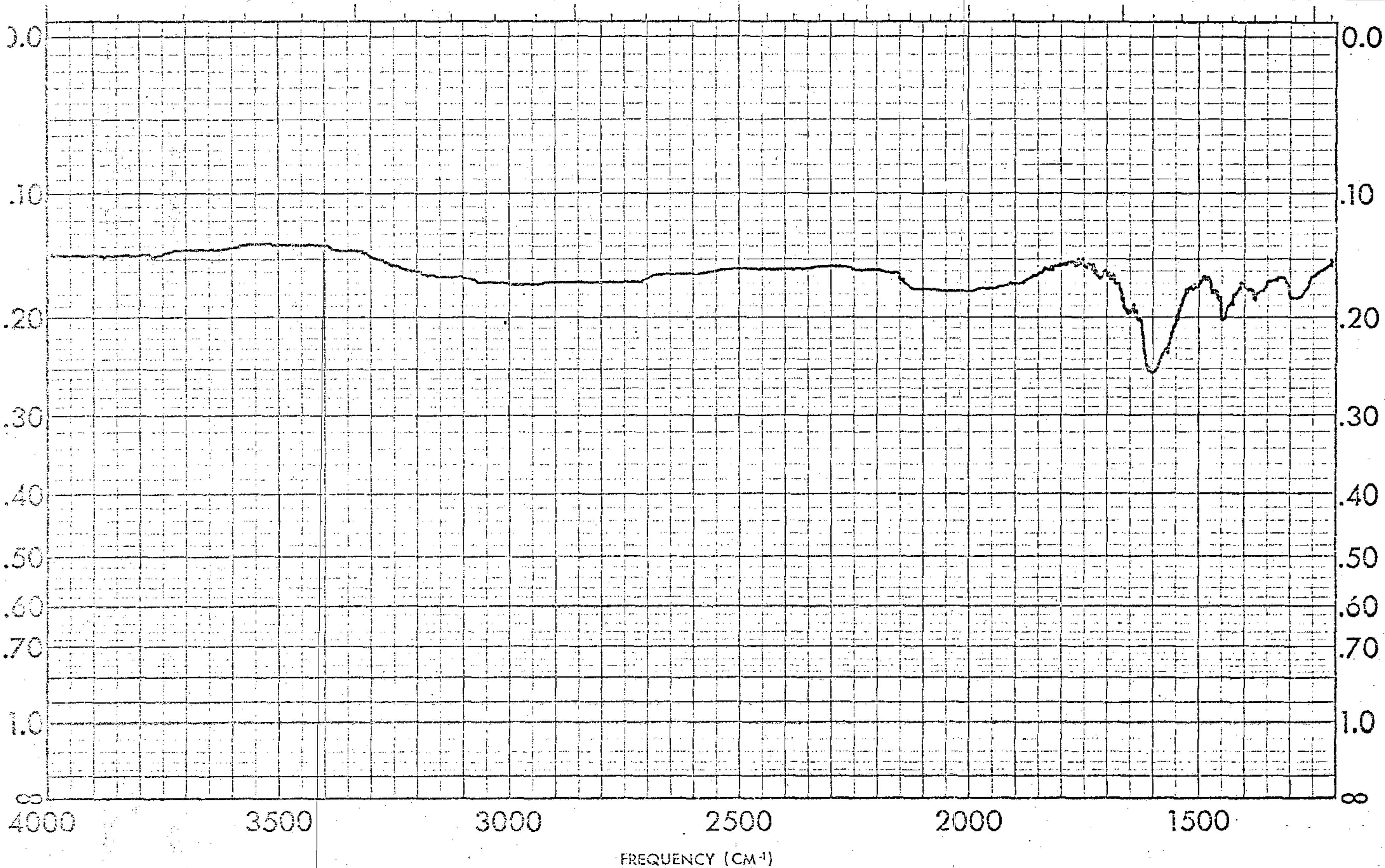
Spectrum No. 79: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$ by A.T.R.



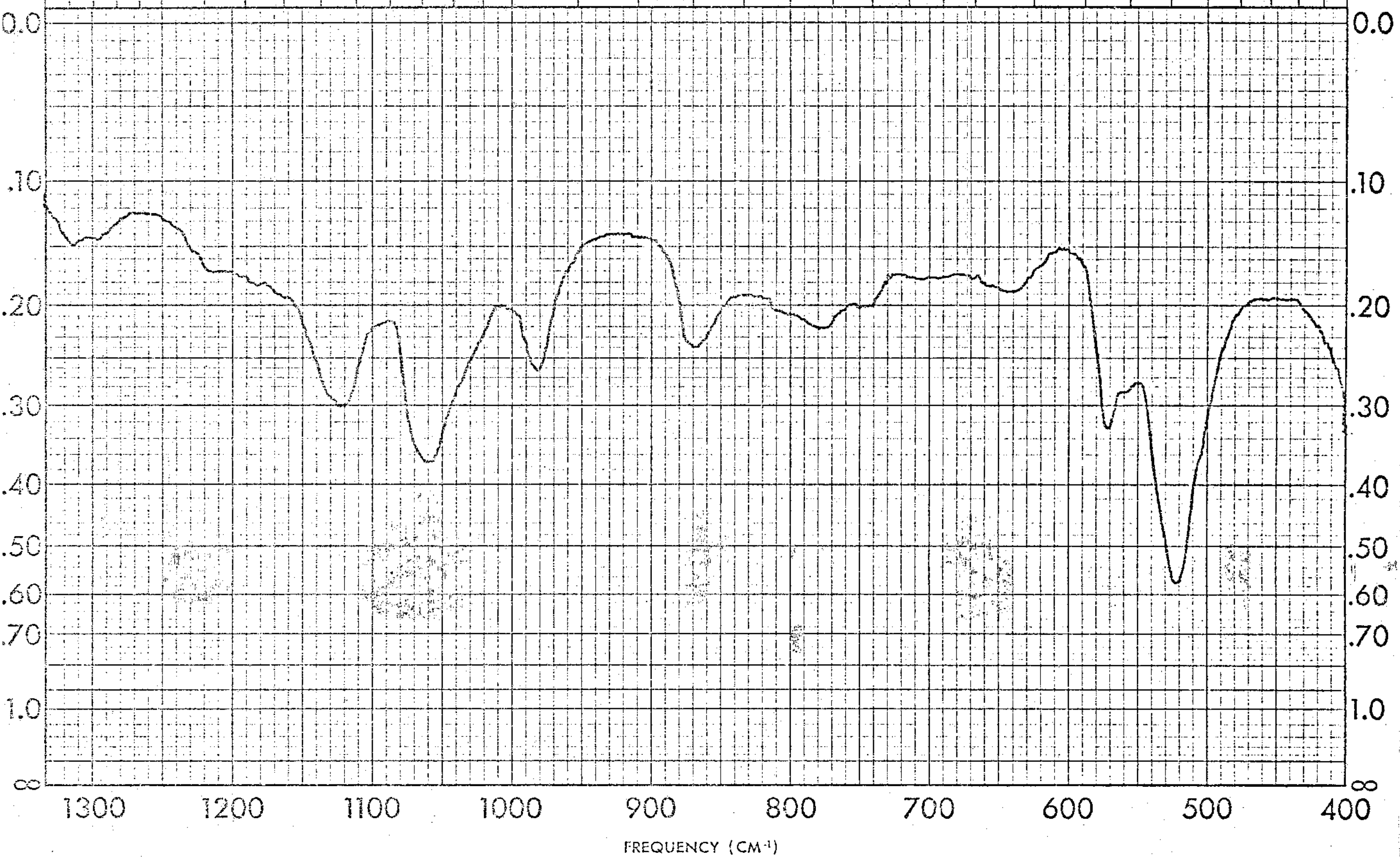
Spectrum No. 80: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



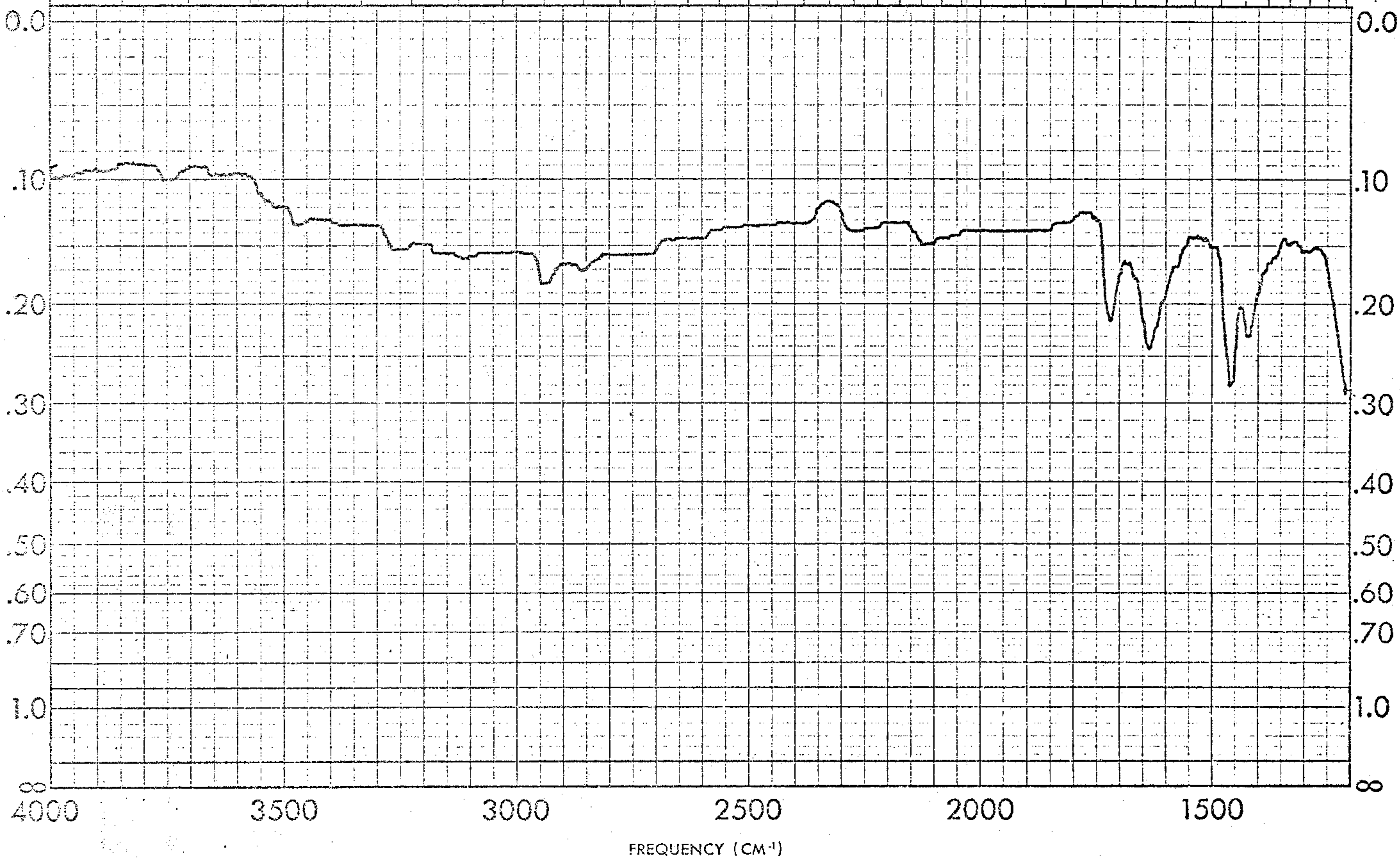
Spectrum No. 80: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



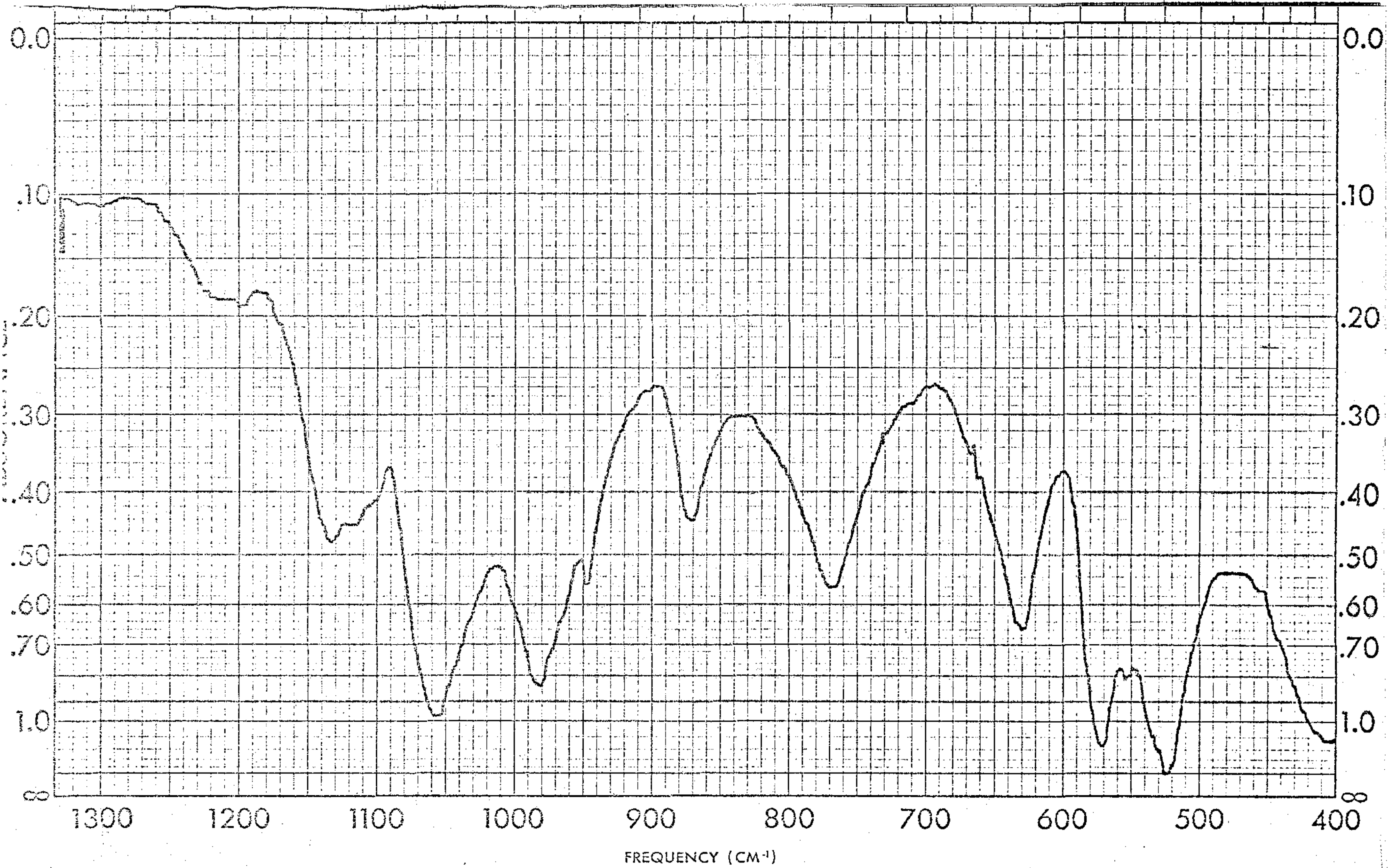
Spectrum No. 81: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ by A.T.R.



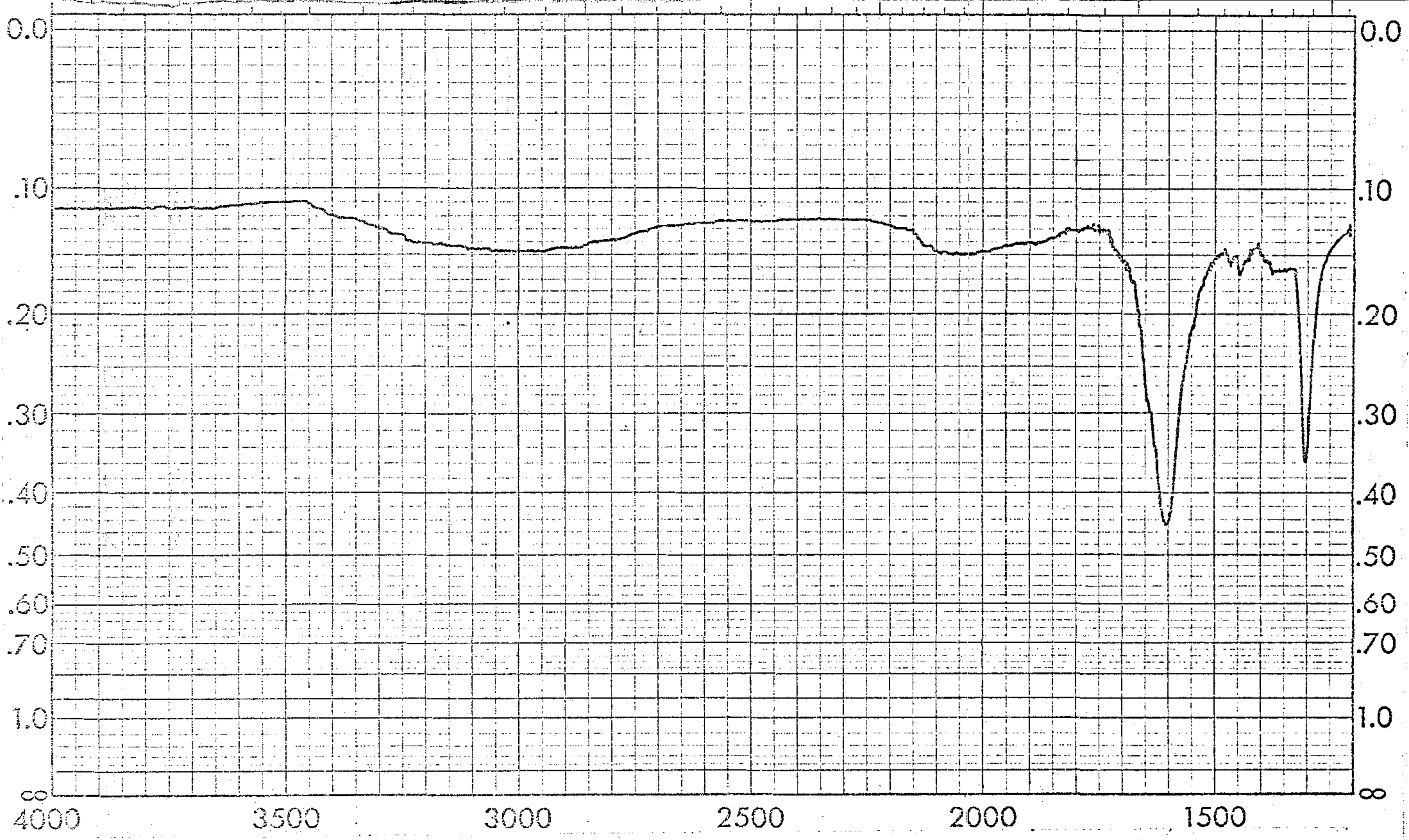
Spectrum No. 81: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Calcium Hydrogen Phosphate, $CaHPO_4$ by A.T.R.



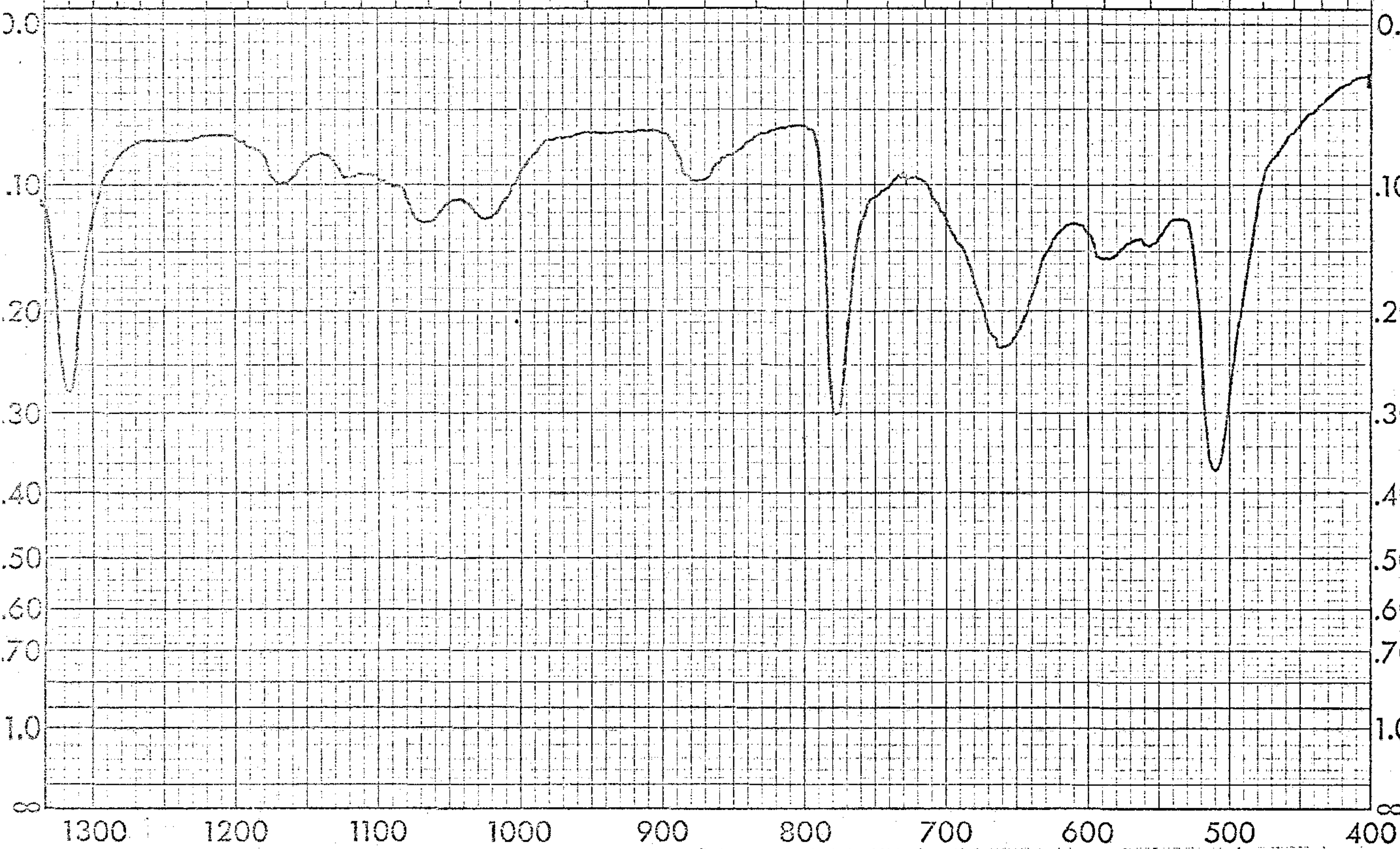
Spectrum No. 82: 50% Calcium Hydrogen Phosphate, $CaHPO_4$, and 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ by A.T.R.



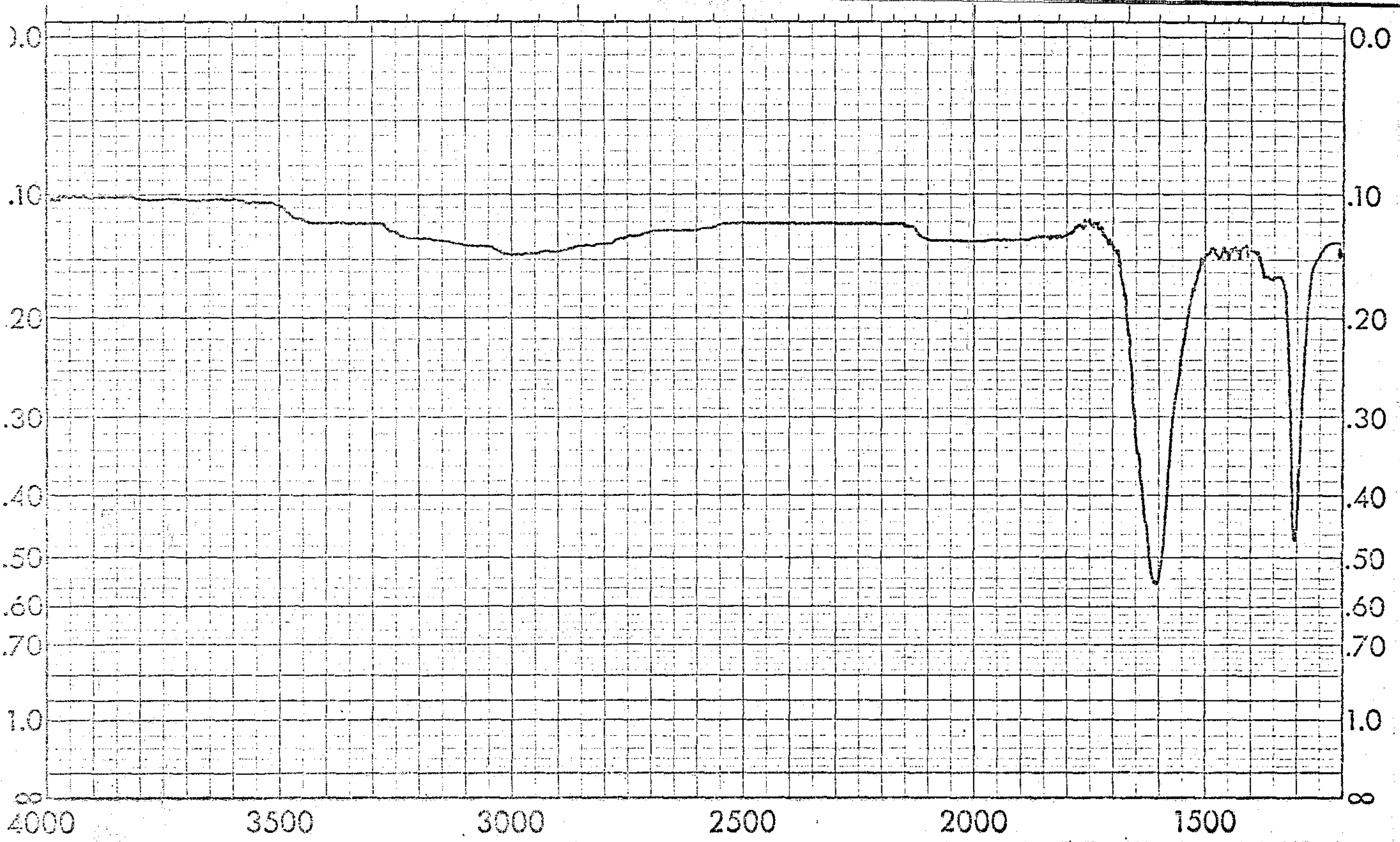
Spectrum No. 82: 50% Calcium Hydrogen Phosphate, $CaHPO_4$, and 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ by A.T.R.



Spectrum No. 83: 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ and 50% Magnesium Phosphate, $MgHPO_4$ by A.T.R.

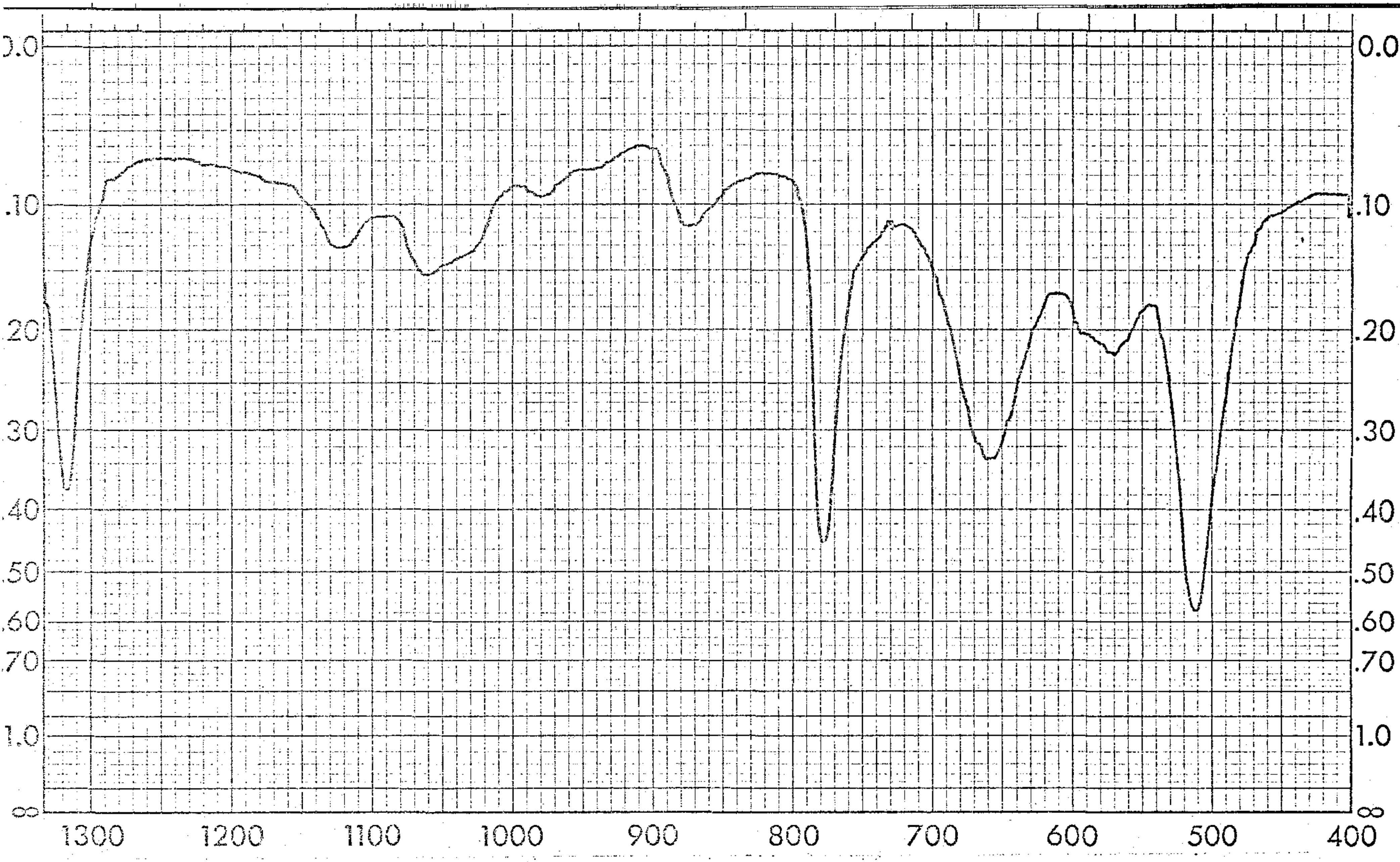


Spectrum No. 83: 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, and 50% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



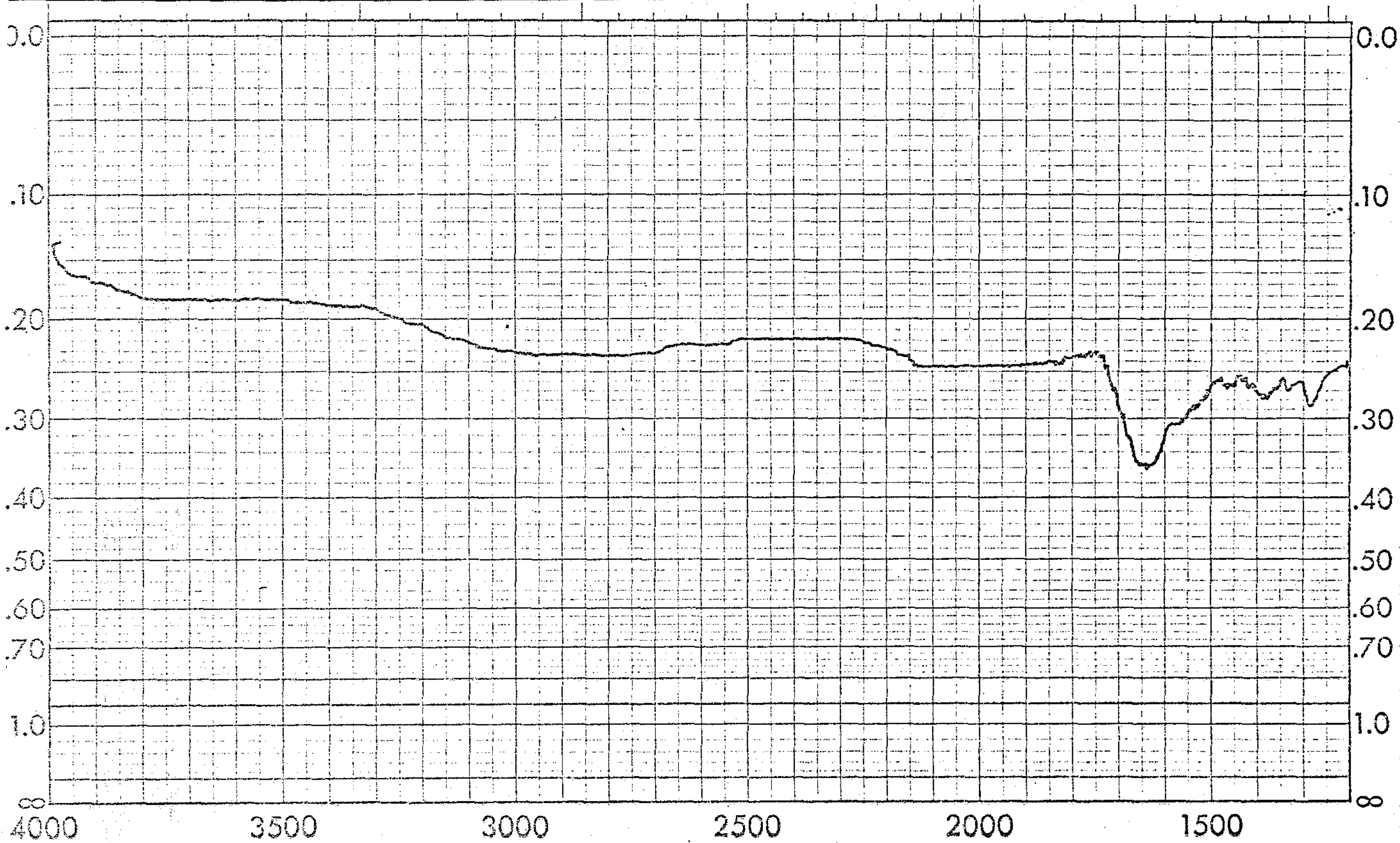
Spectrum No. 84: 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, and

50% Calcium Hydrogen Phosphate, $CaHPO_4$ by A.T.R.

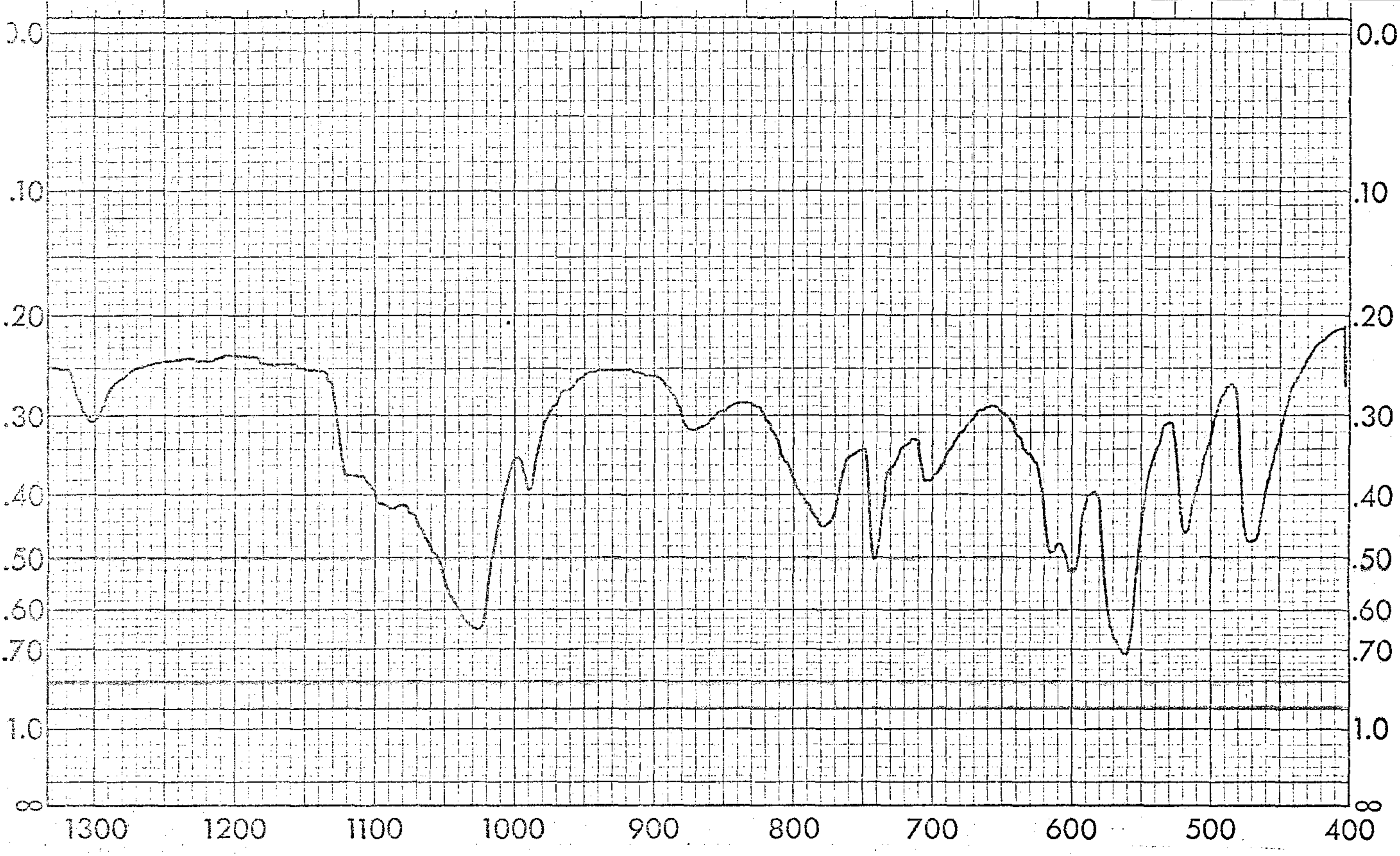


Spectrum No. 84: 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, and

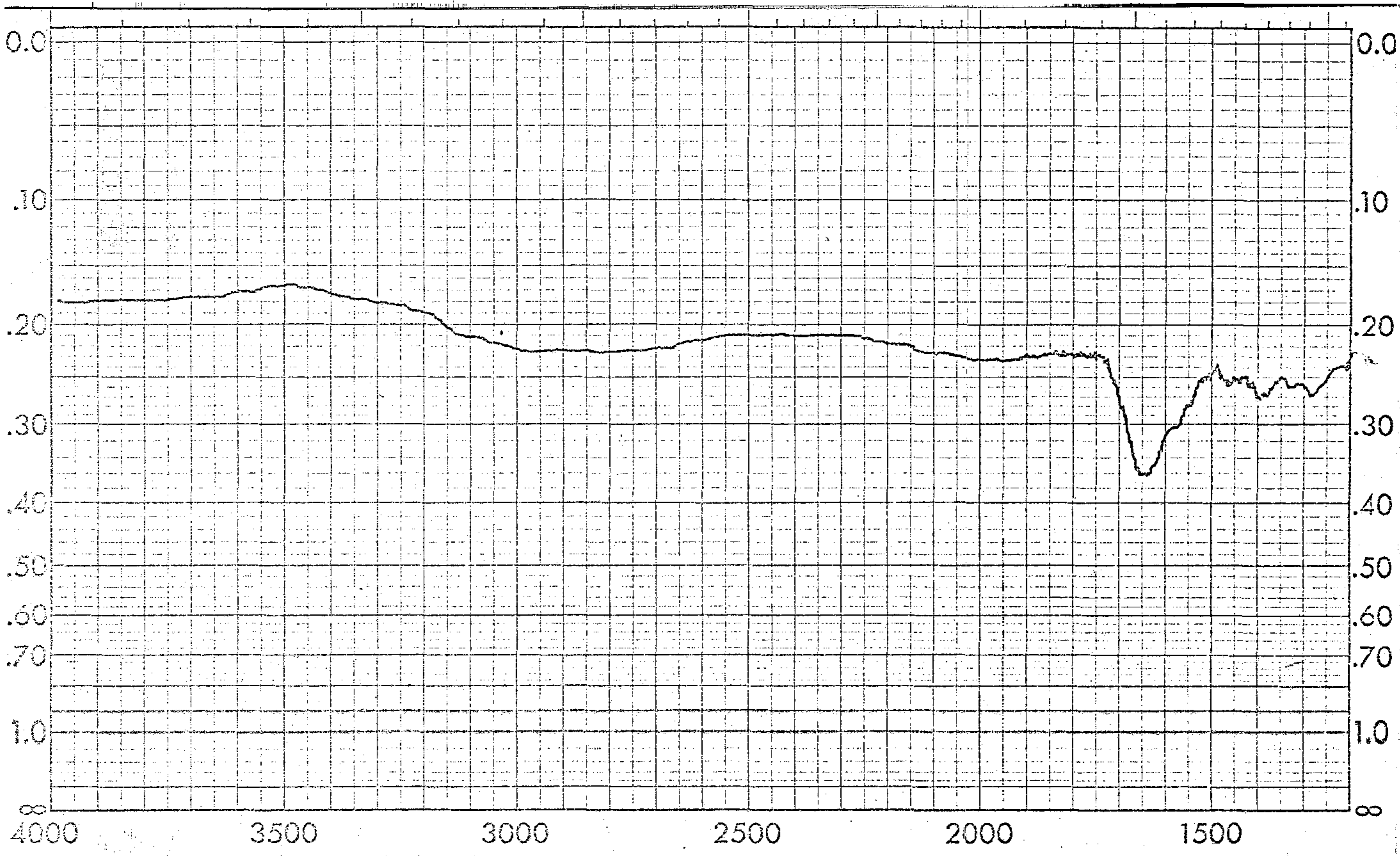
50% Calcium Hydrogen Phosphate, $CaHPO_4$ by A.T.R.



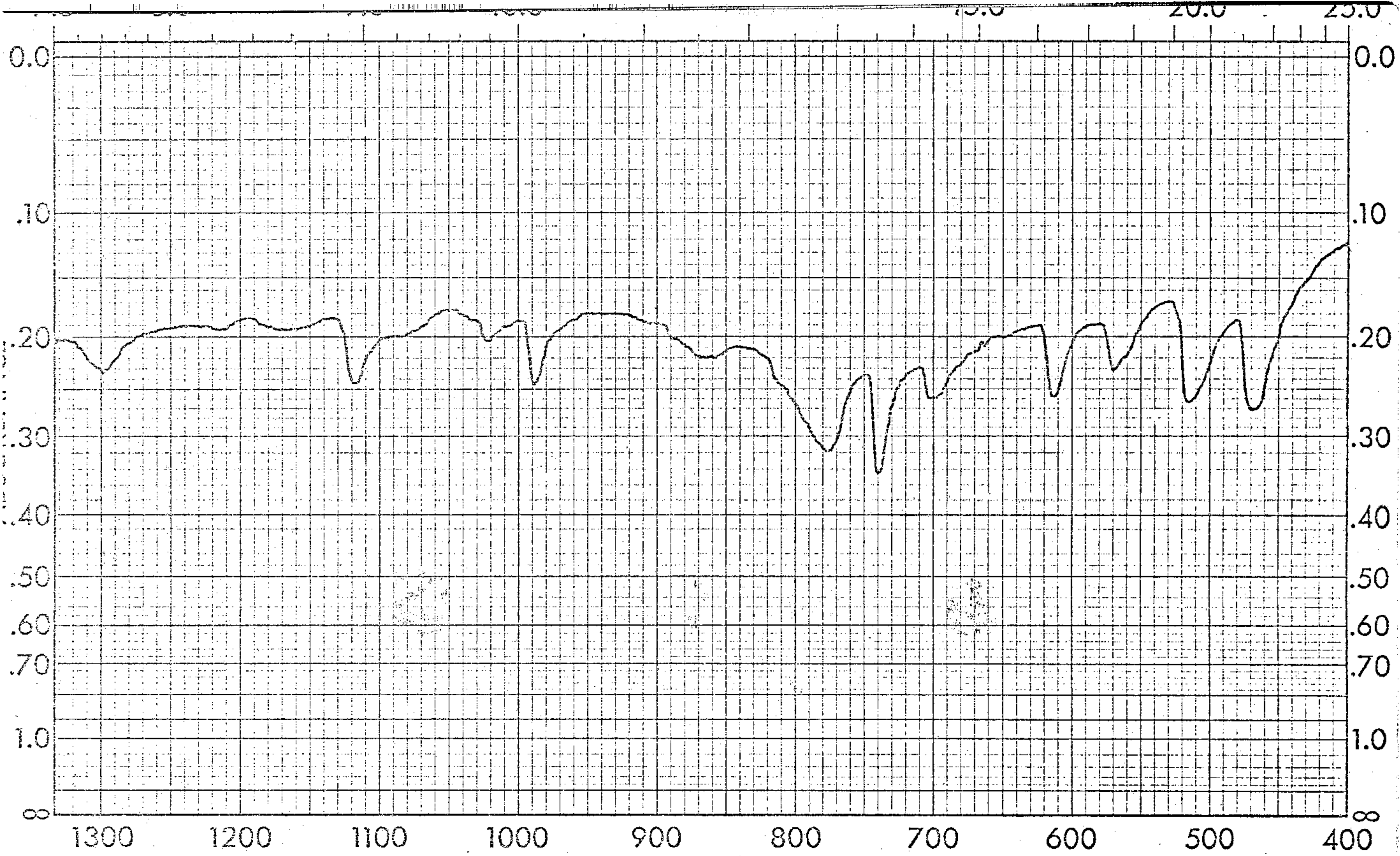
Spectrum No. 85: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$ by A.T.R.



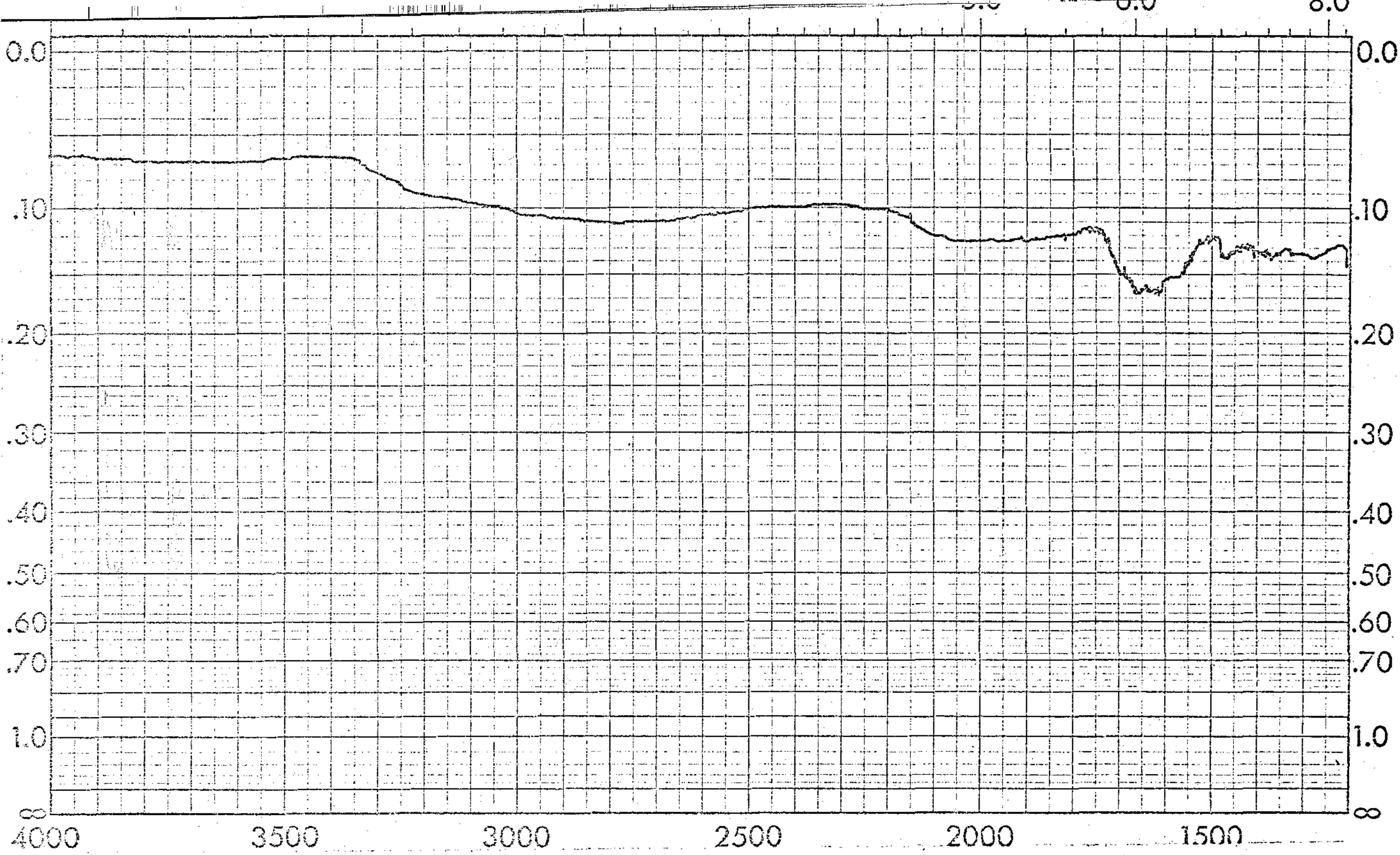
Spectrum No. 85: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$ by A.T.R.



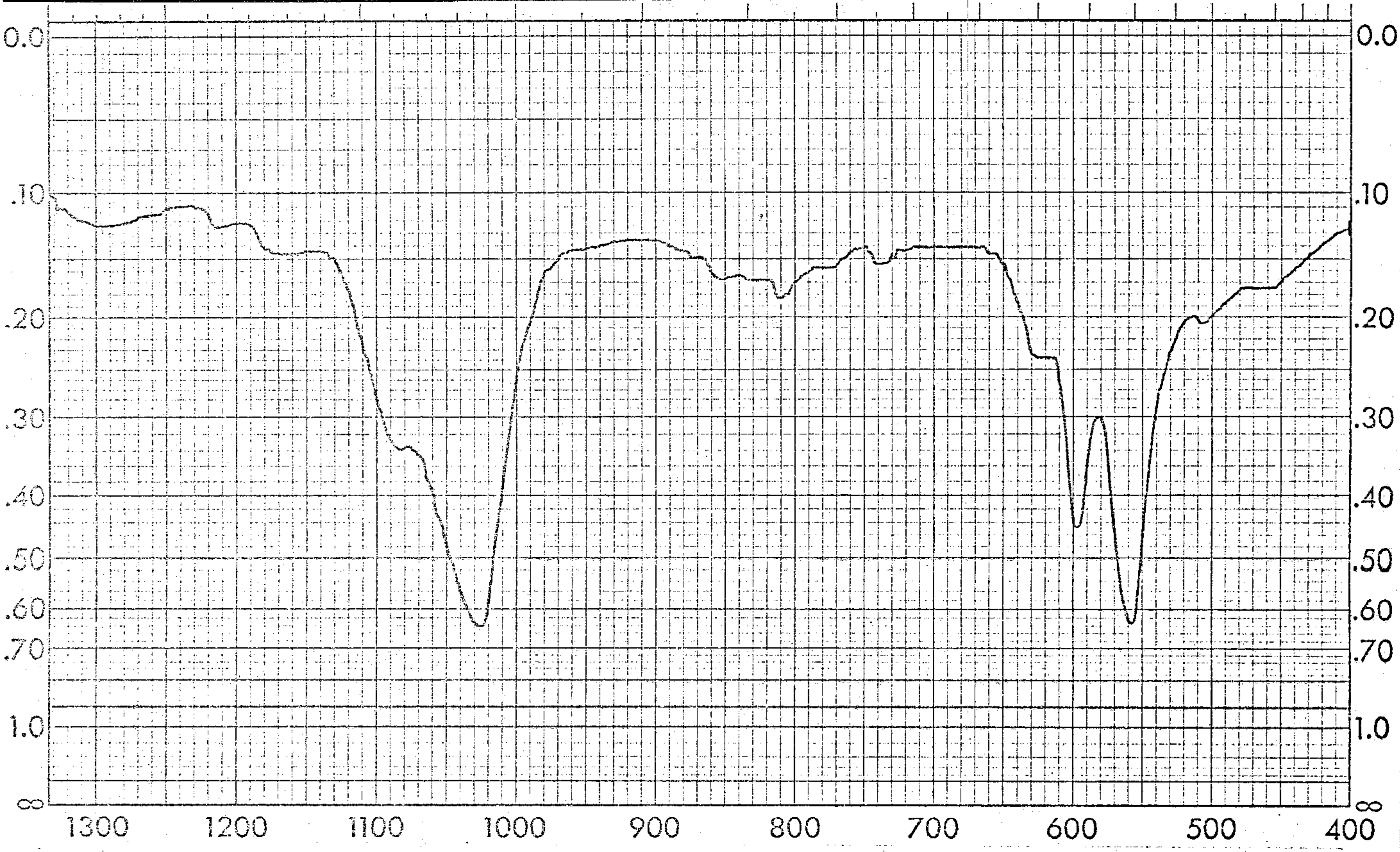
Spectrum No. 86: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Cystine, $SCH_2CH(NH_2)-COOH$ by A.T.R.



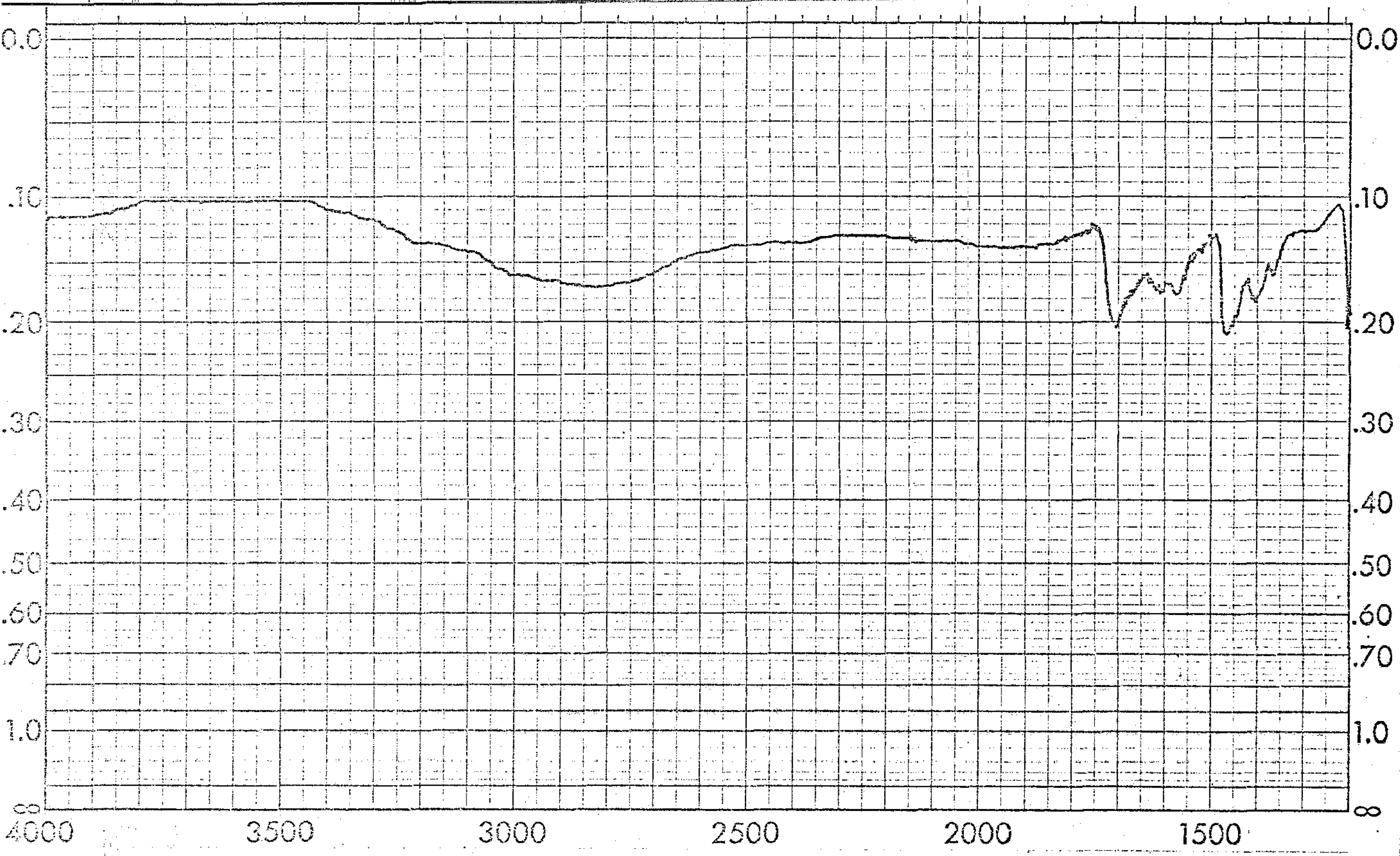
Spectrum No. 86: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Cystine, $SCH_2CH(NH_2)$-COOH by A.T.R.



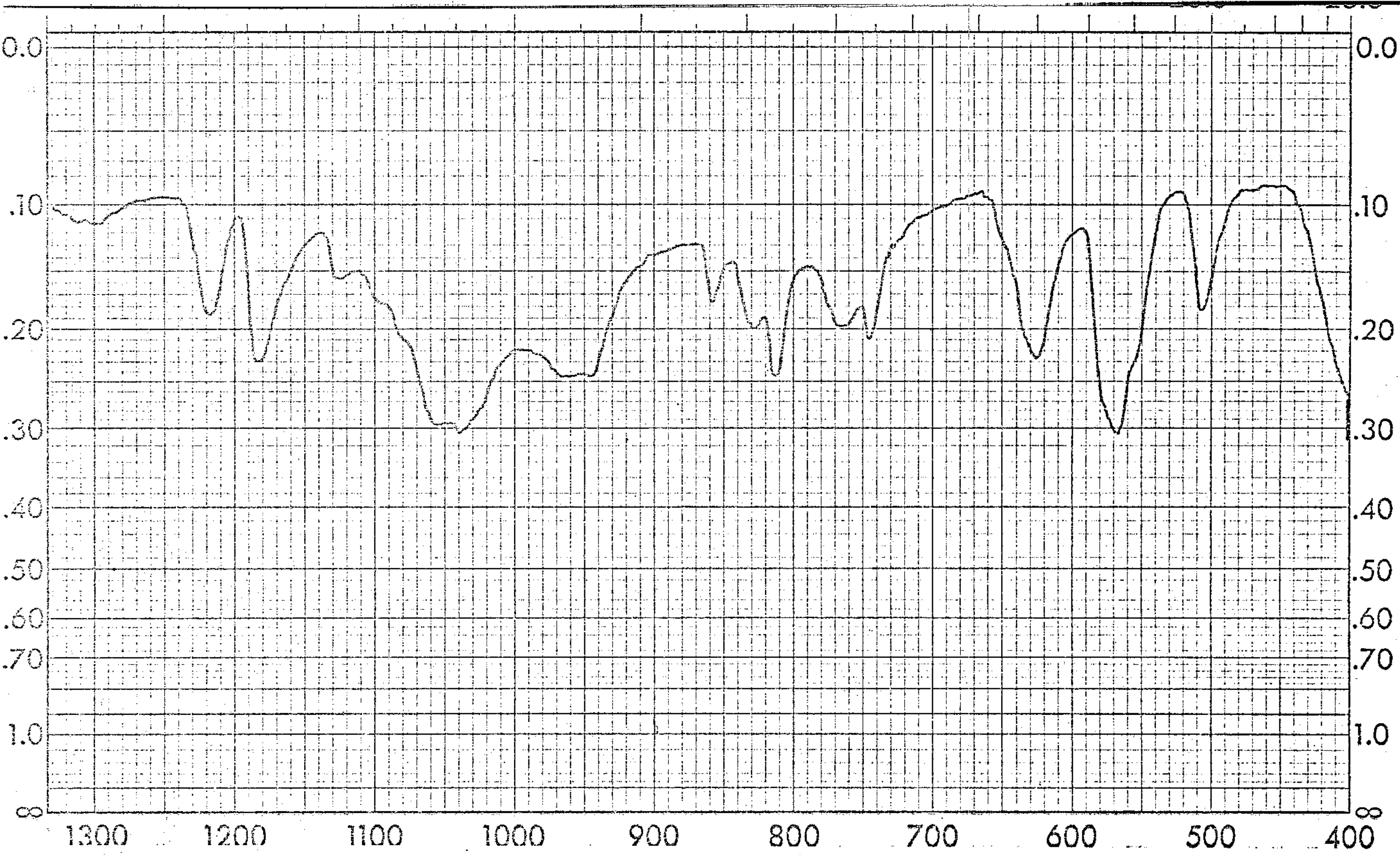
Spectrum No. 87: 50% Cystine, $SCH_2CH(NH_2)$-COOH, and 50% Tricalcium Phosphate $Ca_3(PO_4)_2$ by A.T.R.



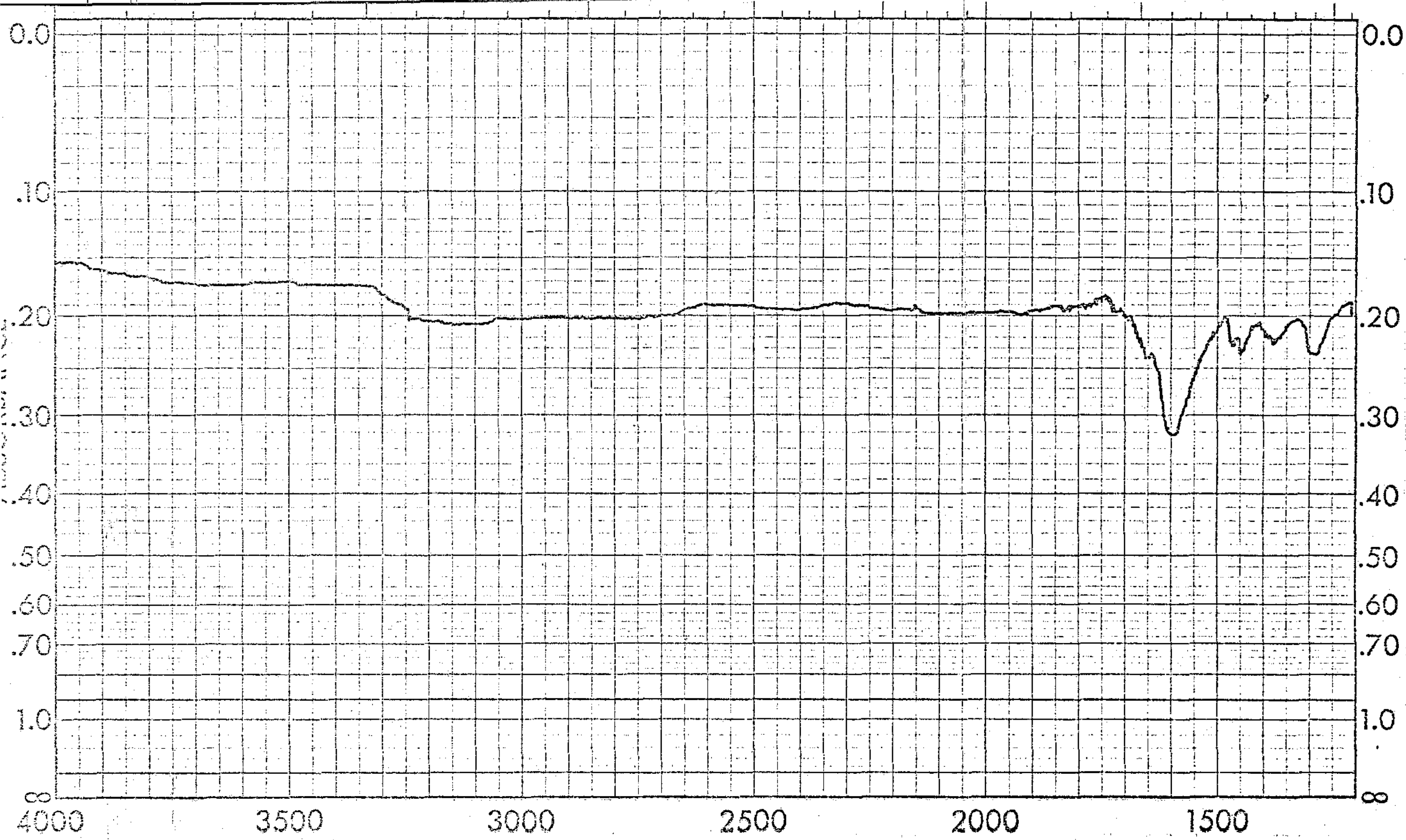
Spectrum No. 87: 50% Cystine, $SCH_2CH(NH_2)$-COOH, and 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$ by A.T.R.



Spectrum No. 88: 50% Cystine, $SCH_2CH(NH_2)-COOH$, and 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ by A.T.R.

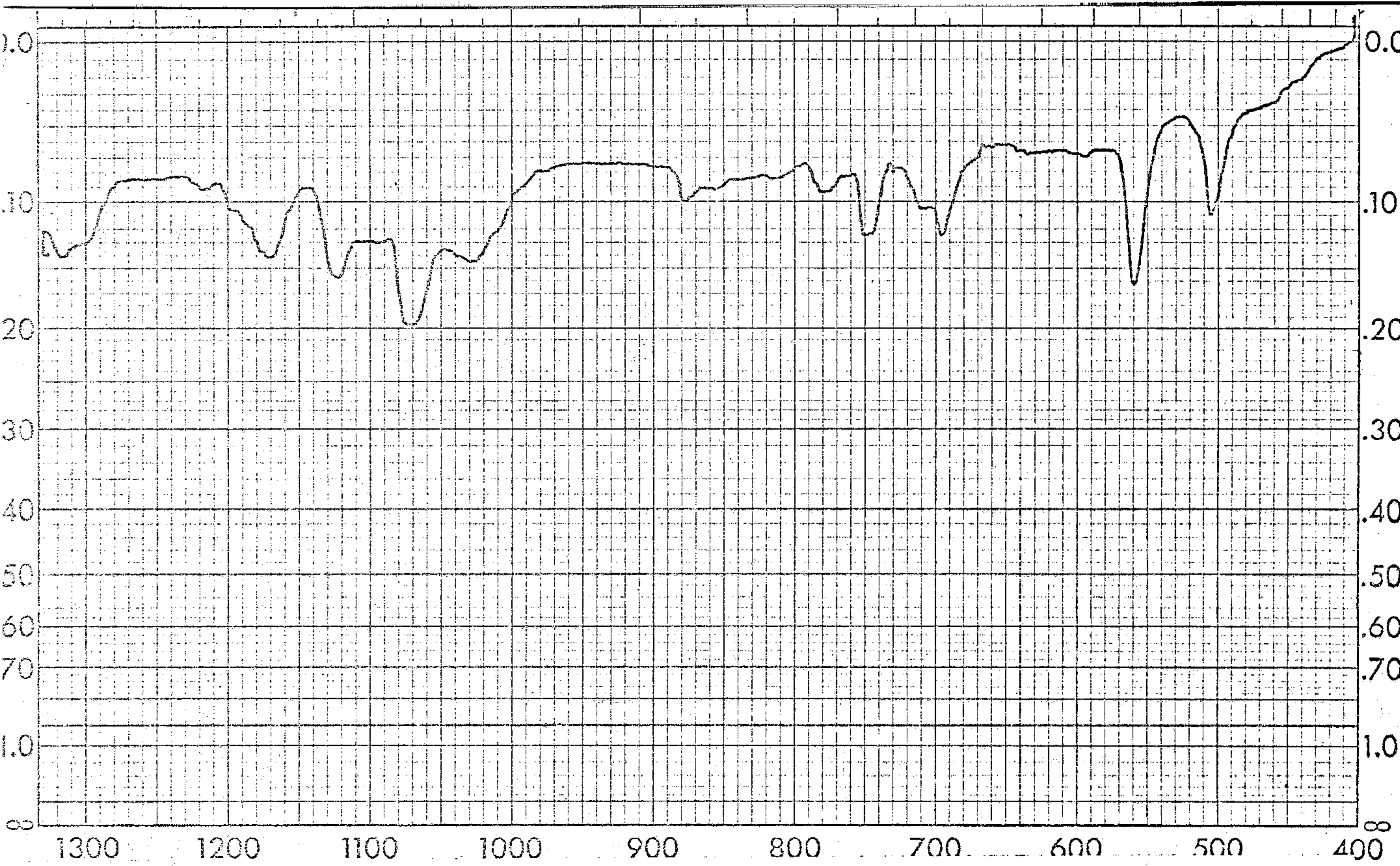


Spectrum No. 88: 50% Cystine, $SCH_2CH(NH_2)$-COOH, and 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ by A.T.R.



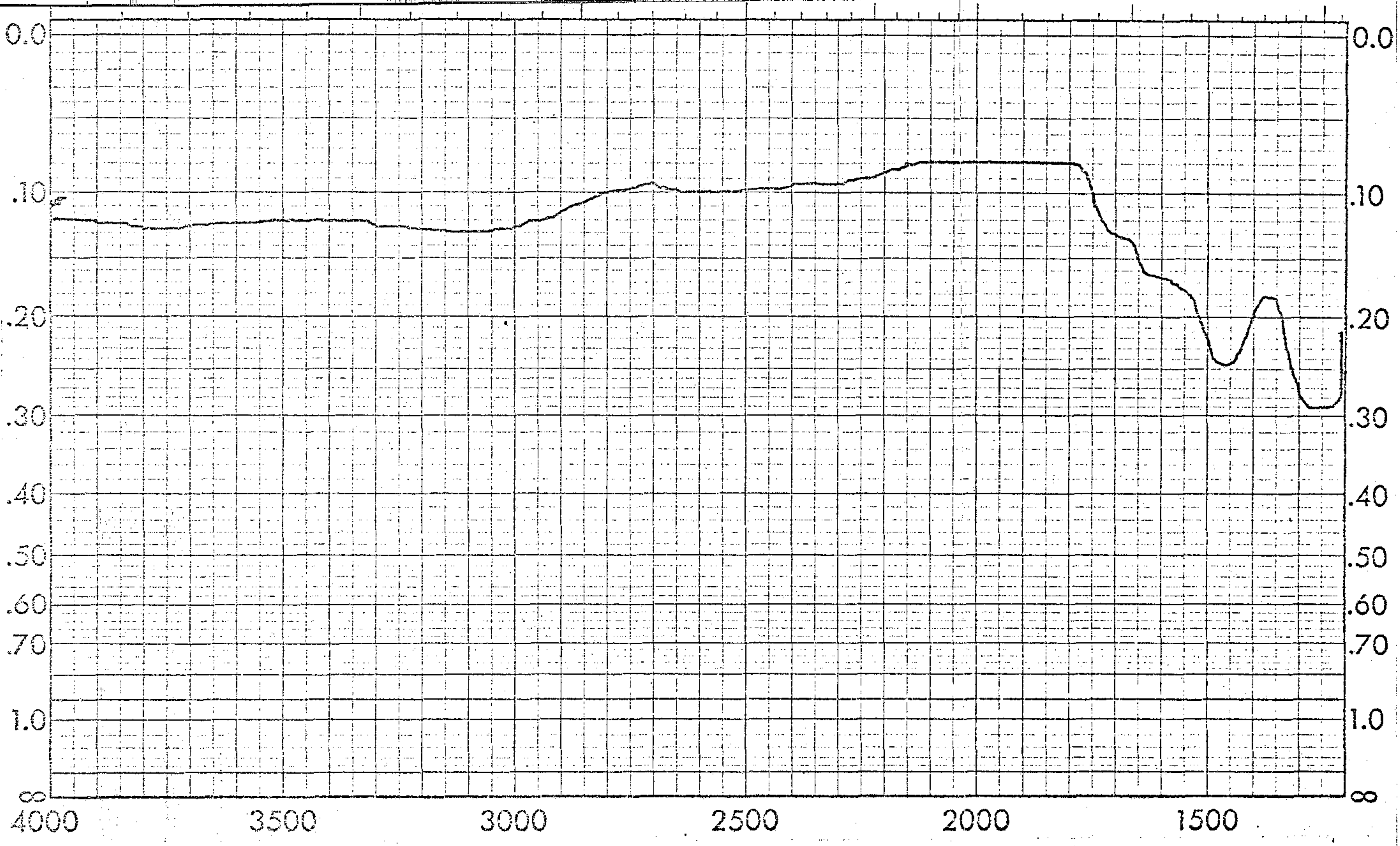
Spectrum No. 89: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Cystine,

$SCH_2CH(NH_2)$-COOH by A.T.R.



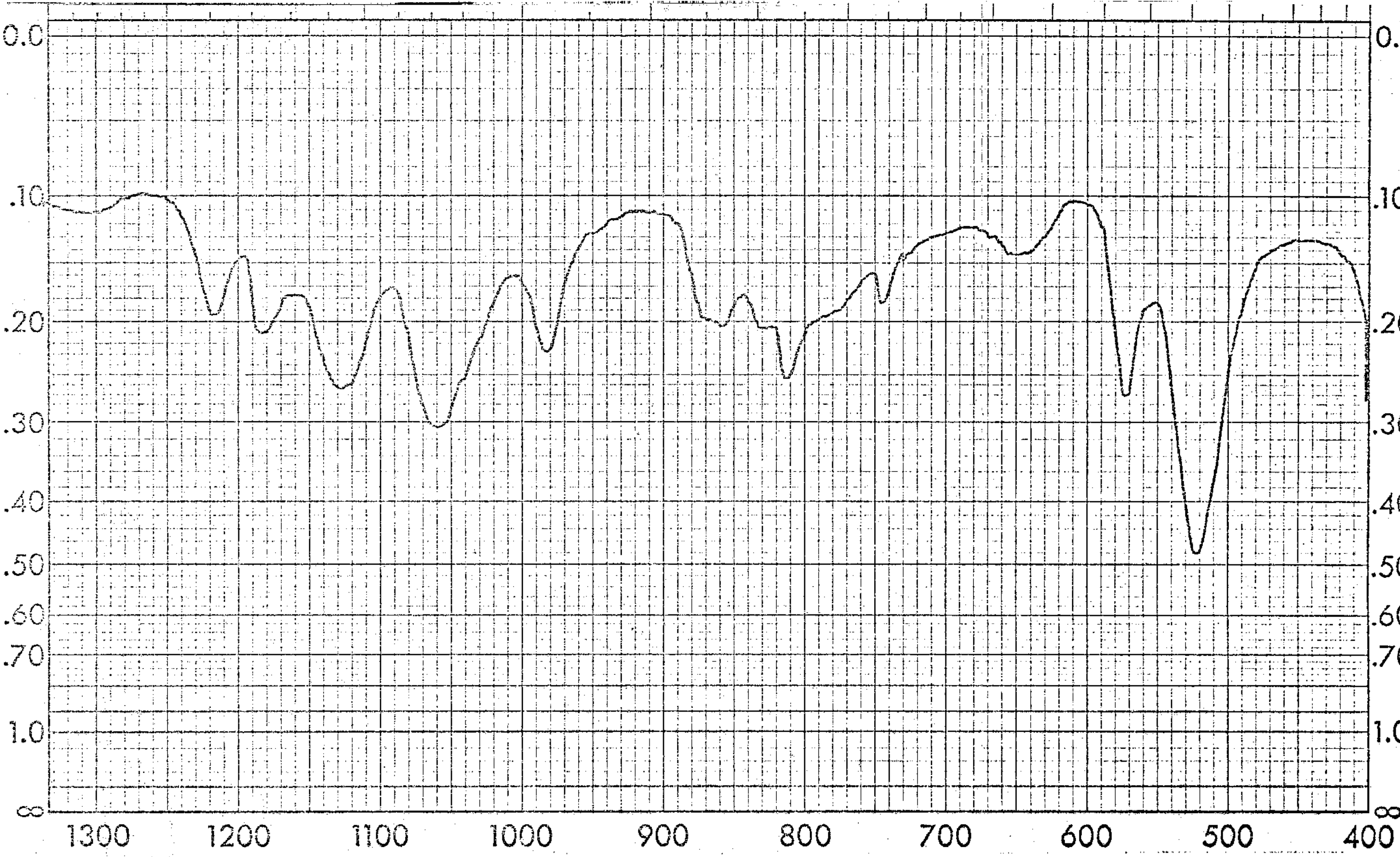
Spectrum No. 89: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Cystine,

$SCH_2CH(NH_2)$-COOH by A.T.R.



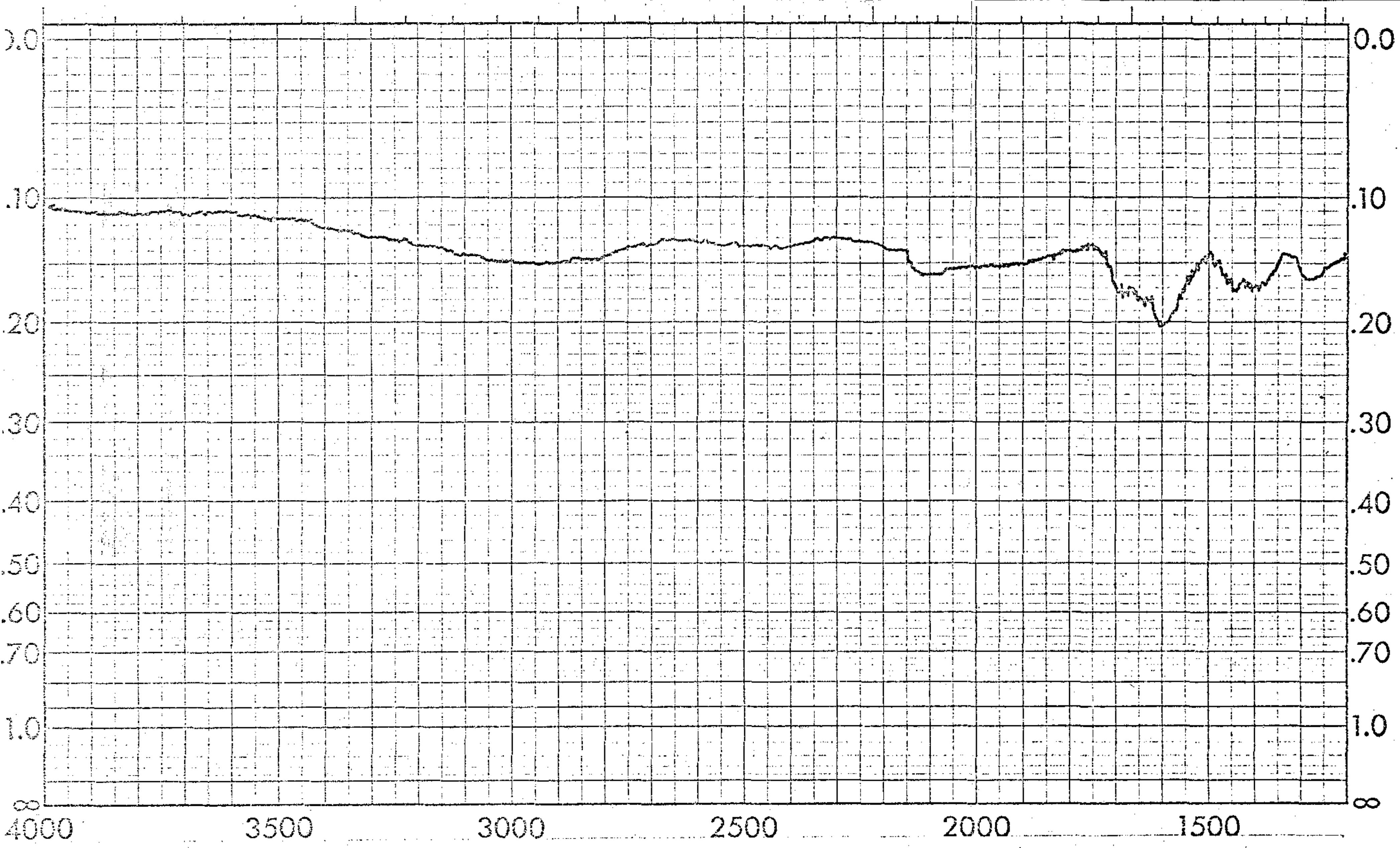
Spectrum No. 90: 50% Cystine, $SCH_2CH(NH_2)$-COOH, and 50% Calcium

Hydrogen Phosphate, $CaHPO_4$ by A.T.R.



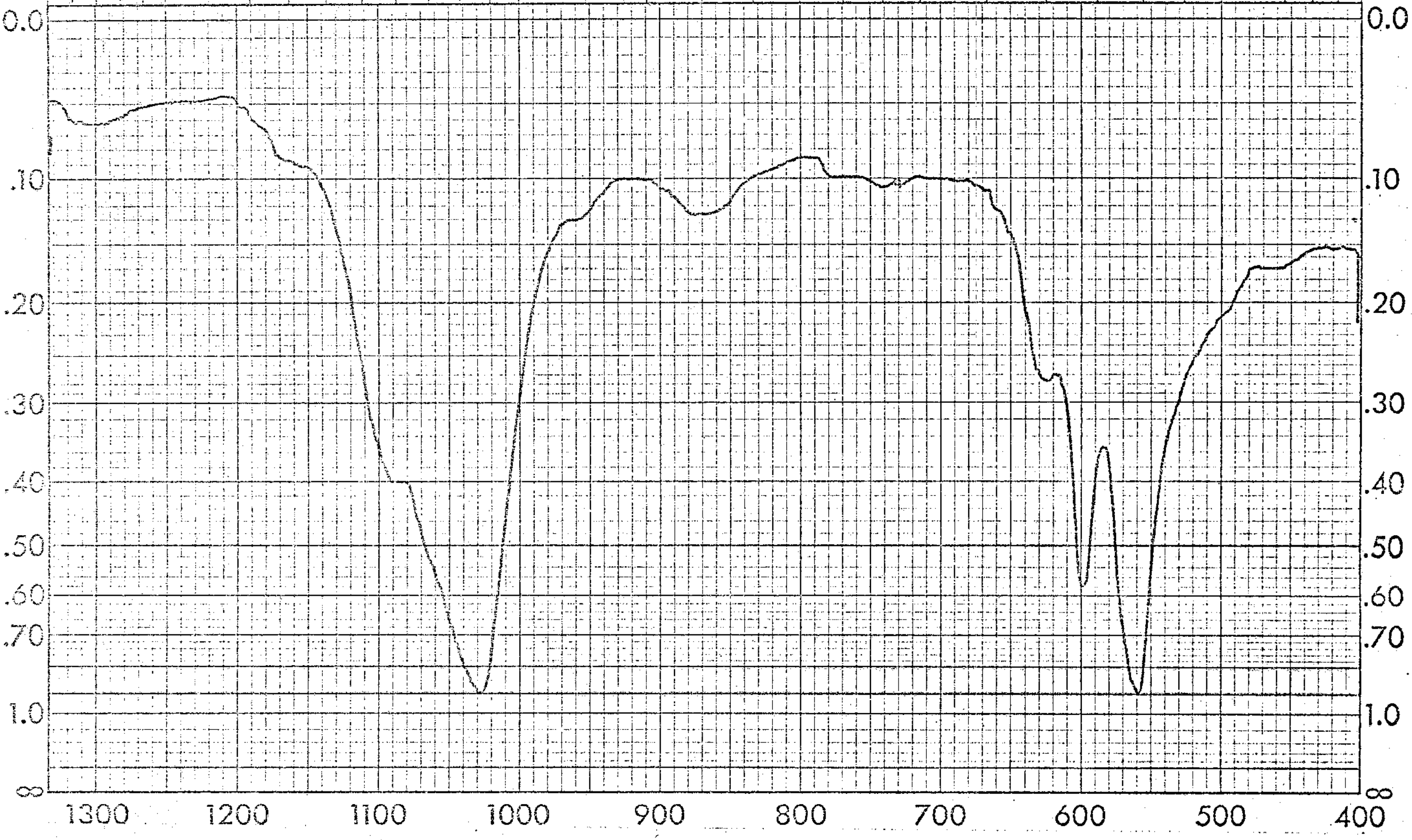
Spectrum No. 90: 50% Cystine, $SCH_2CH(NH_2)$-COOH, and 50% Calcium

Hydrogen Phosphate, $CaHPO_4$ by A.T.R.



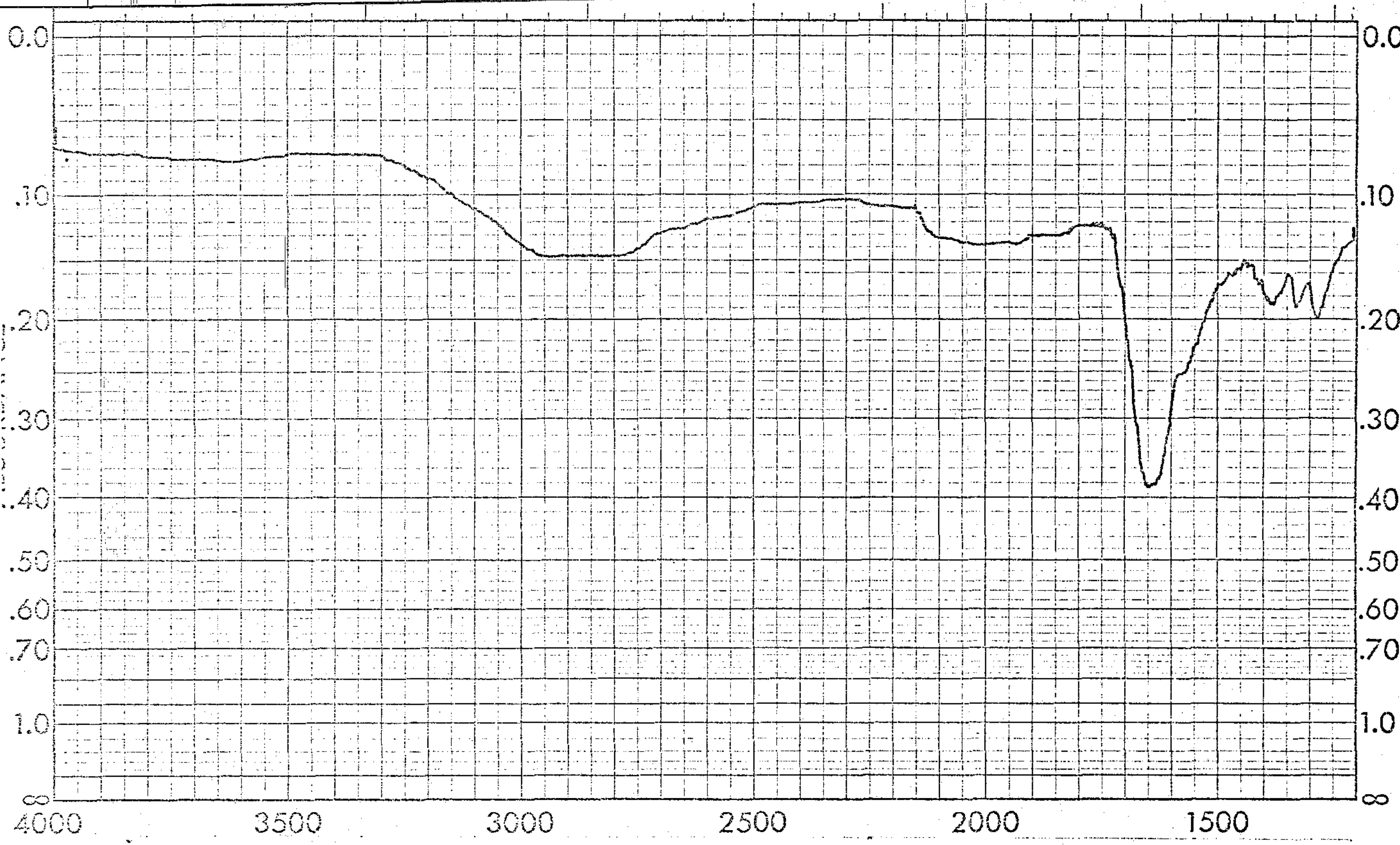
Spectrum No. 91: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50%

Magnesium Ammonium Phosphate, $MgNH_4PO_4$ by A.T.R.



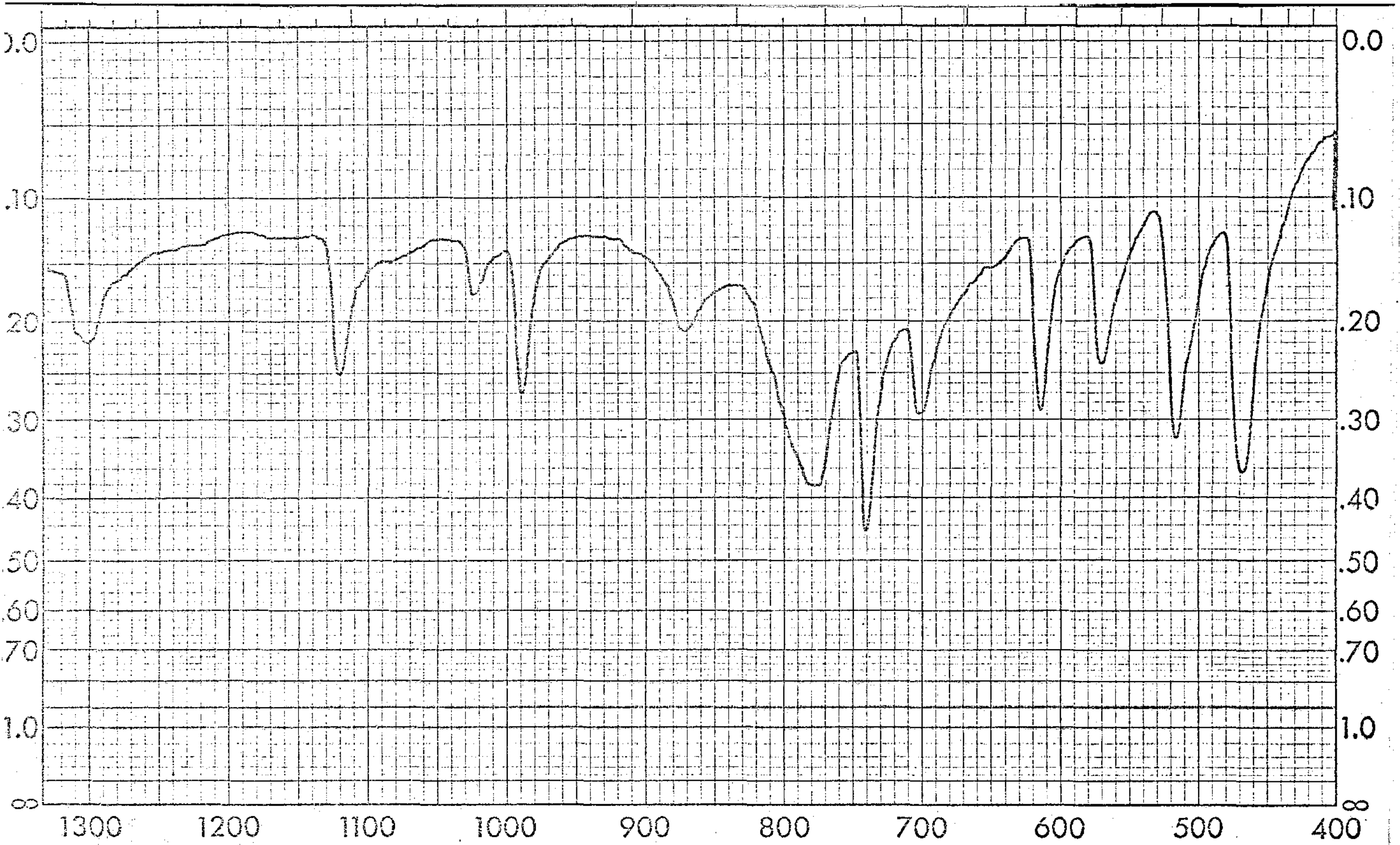
Spectrum No. 91: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 50%

Magnesium Ammonium Phosphate, $MgNH_4PO_4$ by A.T.R.



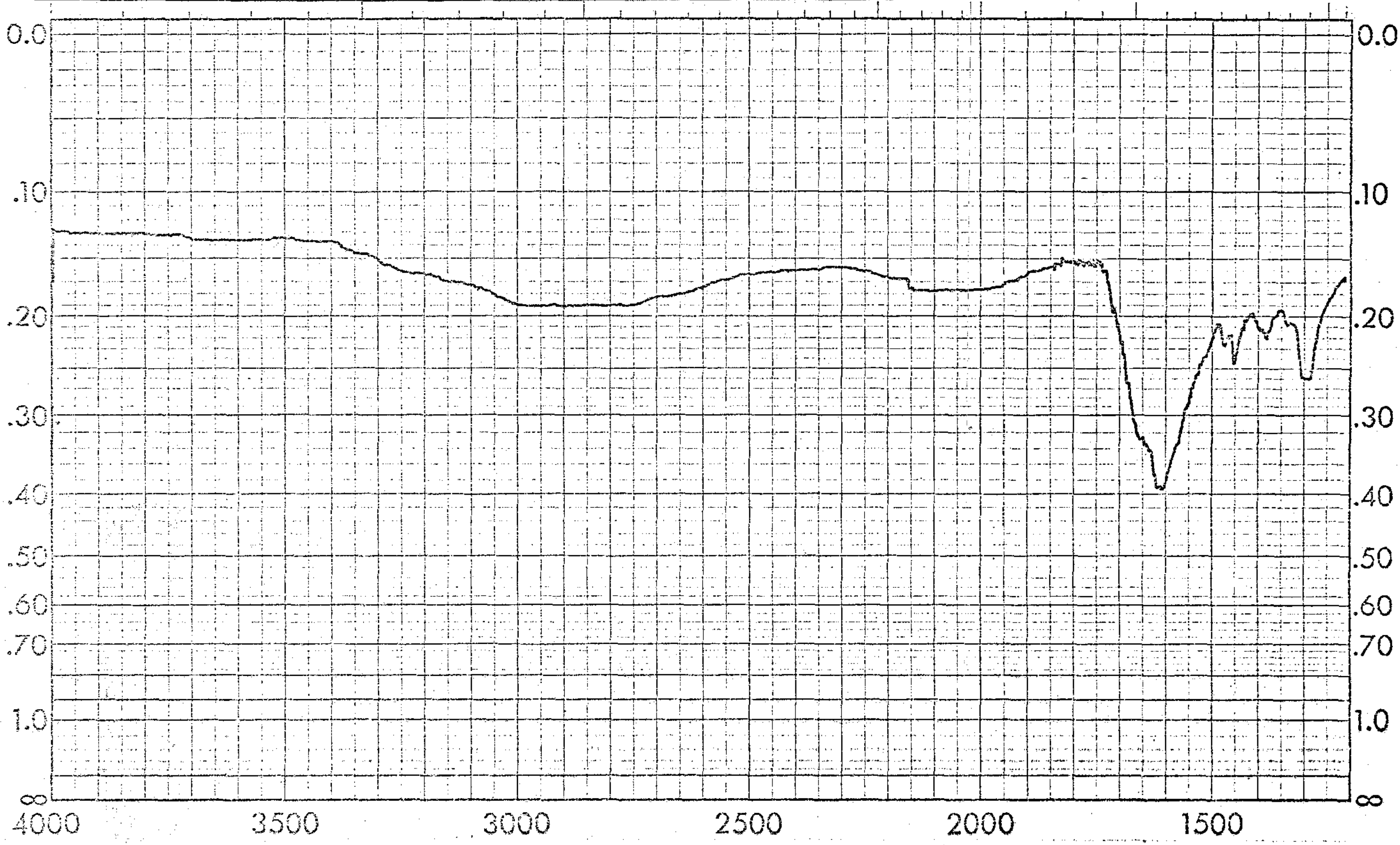
Spectrum No. 92: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Magnesium

Ammonium Phosphate, $MgNH_4PO_4$ by A.T.R.

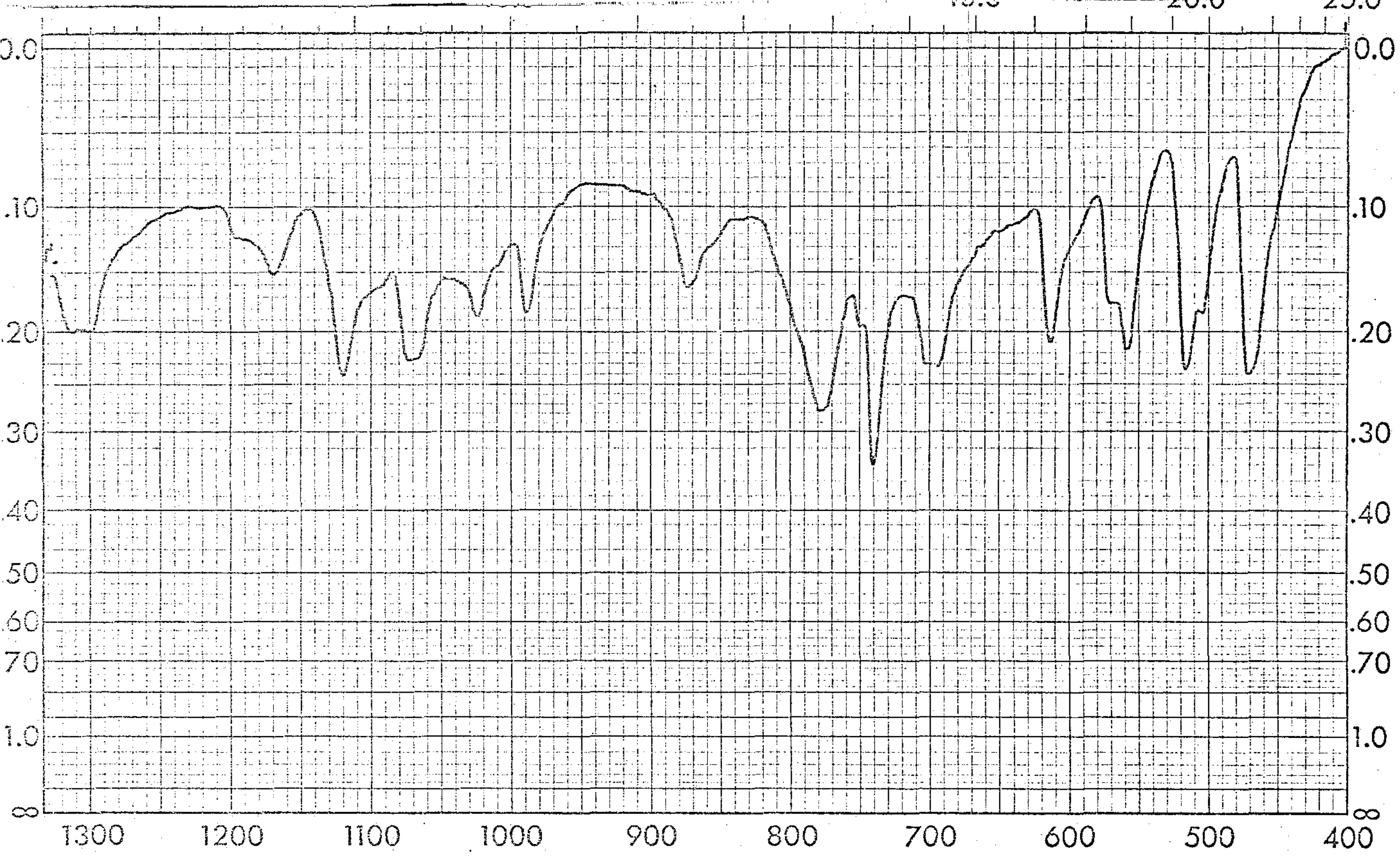


Spectrum No. 92: 50% Uric Acid, $C_5H_4N_4O_3$, and 50% Magnesium

Ammonium Phosphate, $MgNH_4PO_4$ by A.T.R.

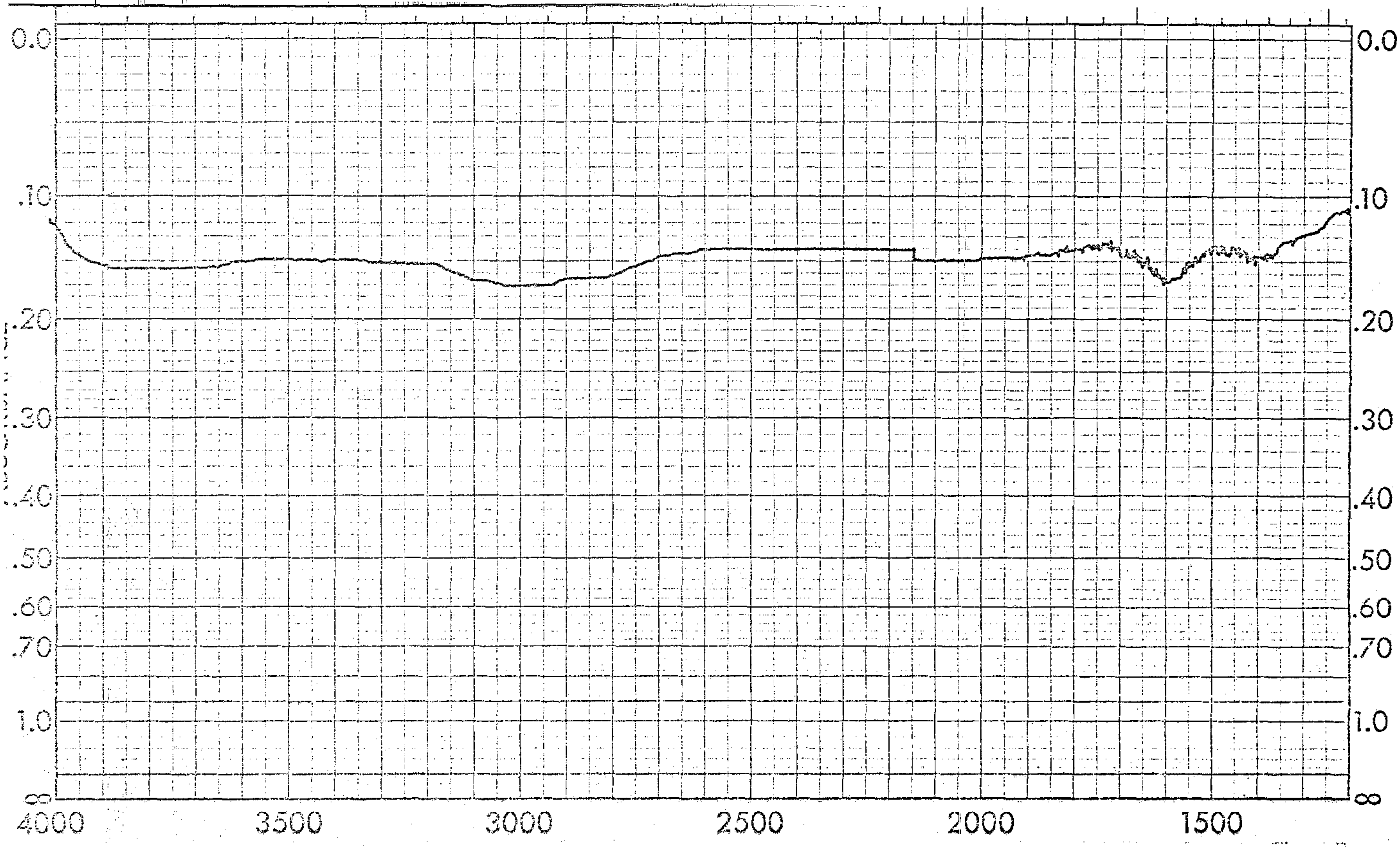


Spectrum No. 95: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Uric Acid, $C_5H_4N_4O_3$ by A.T.R.

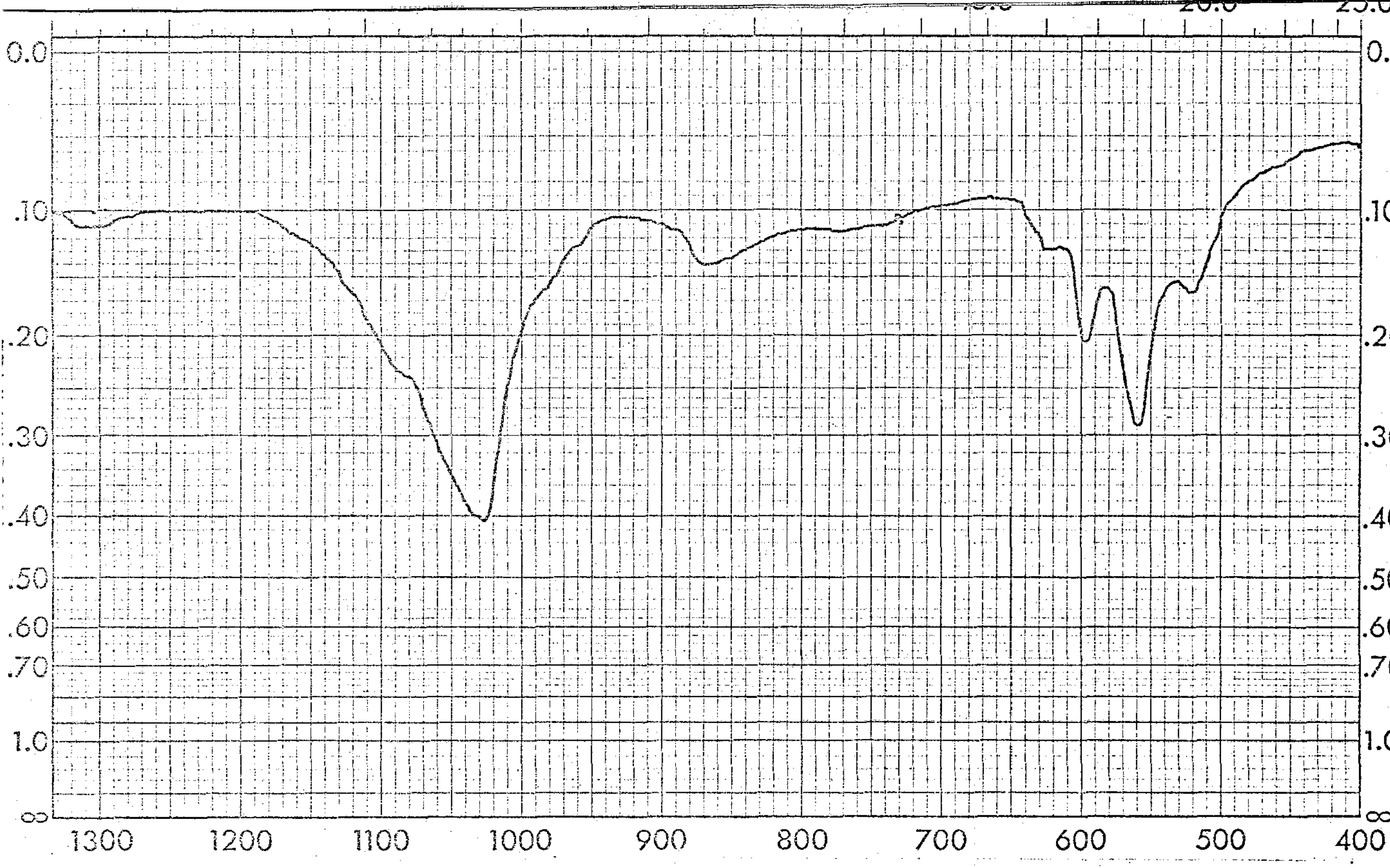


Spectrum No. 93: 50% Indigo, $C_{16}H_{10}N_2O_2$, and 50% Uric Acid,

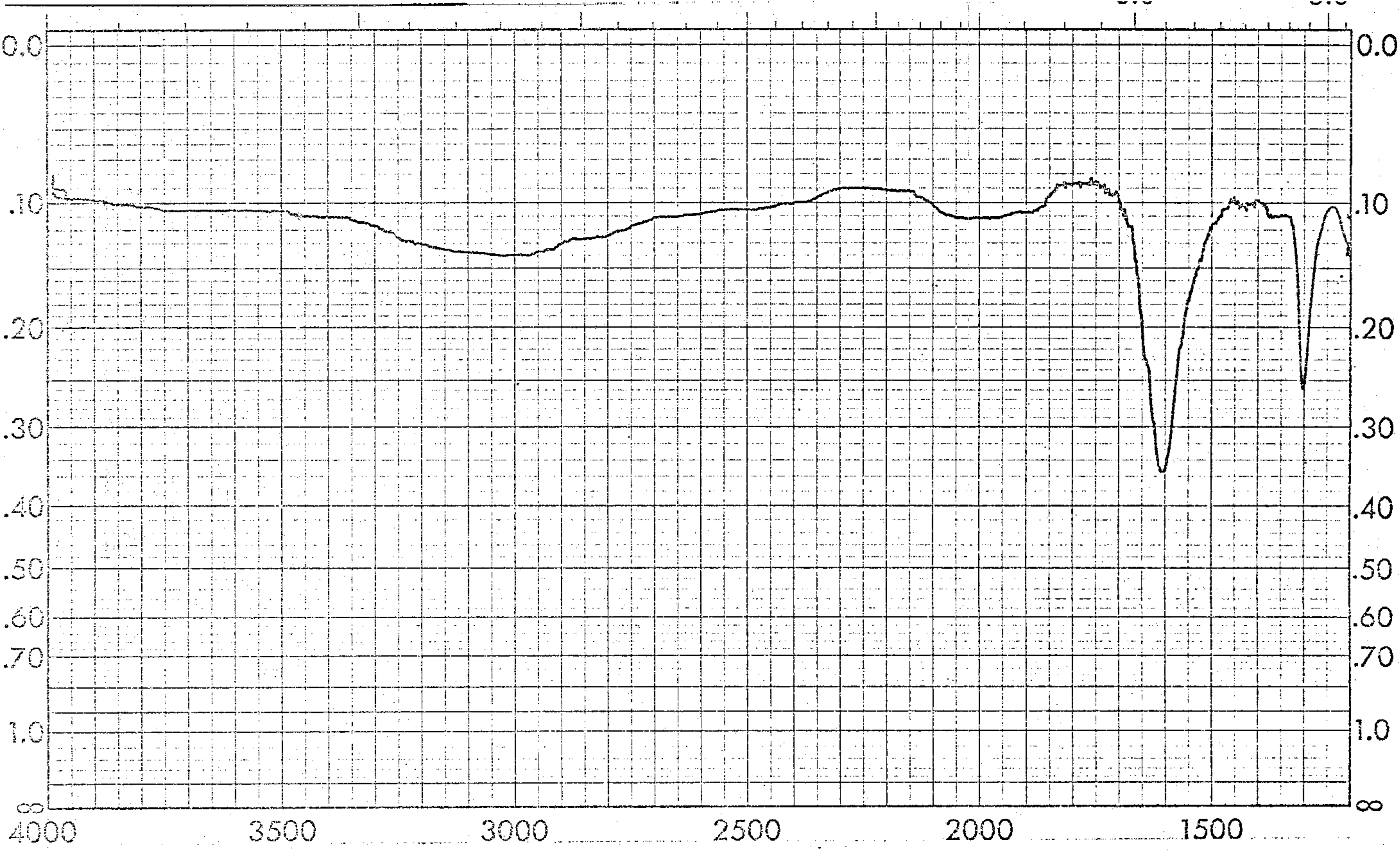
$C_5H_4N_4O_3$ by A.T.R.



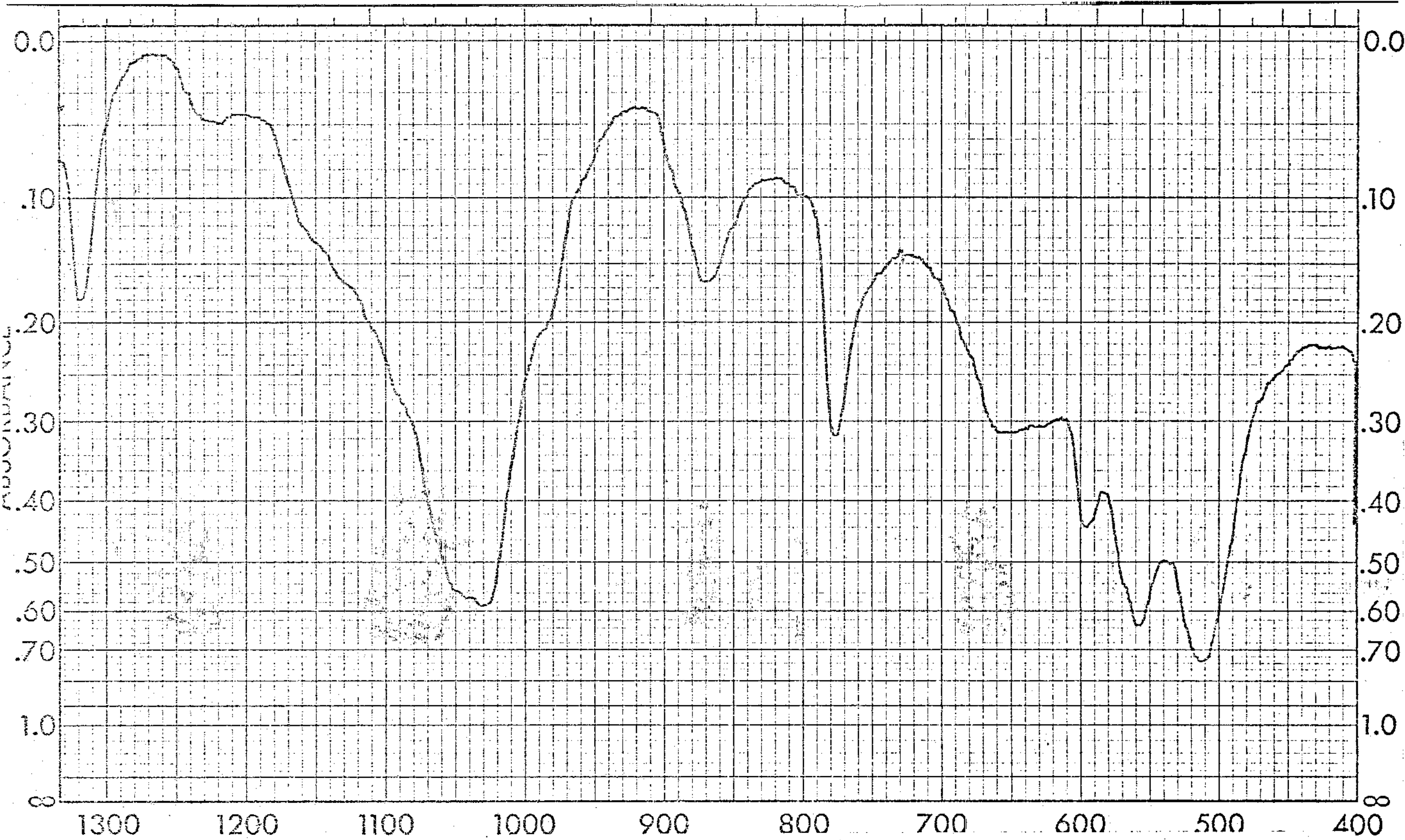
Spectrum No. 94: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



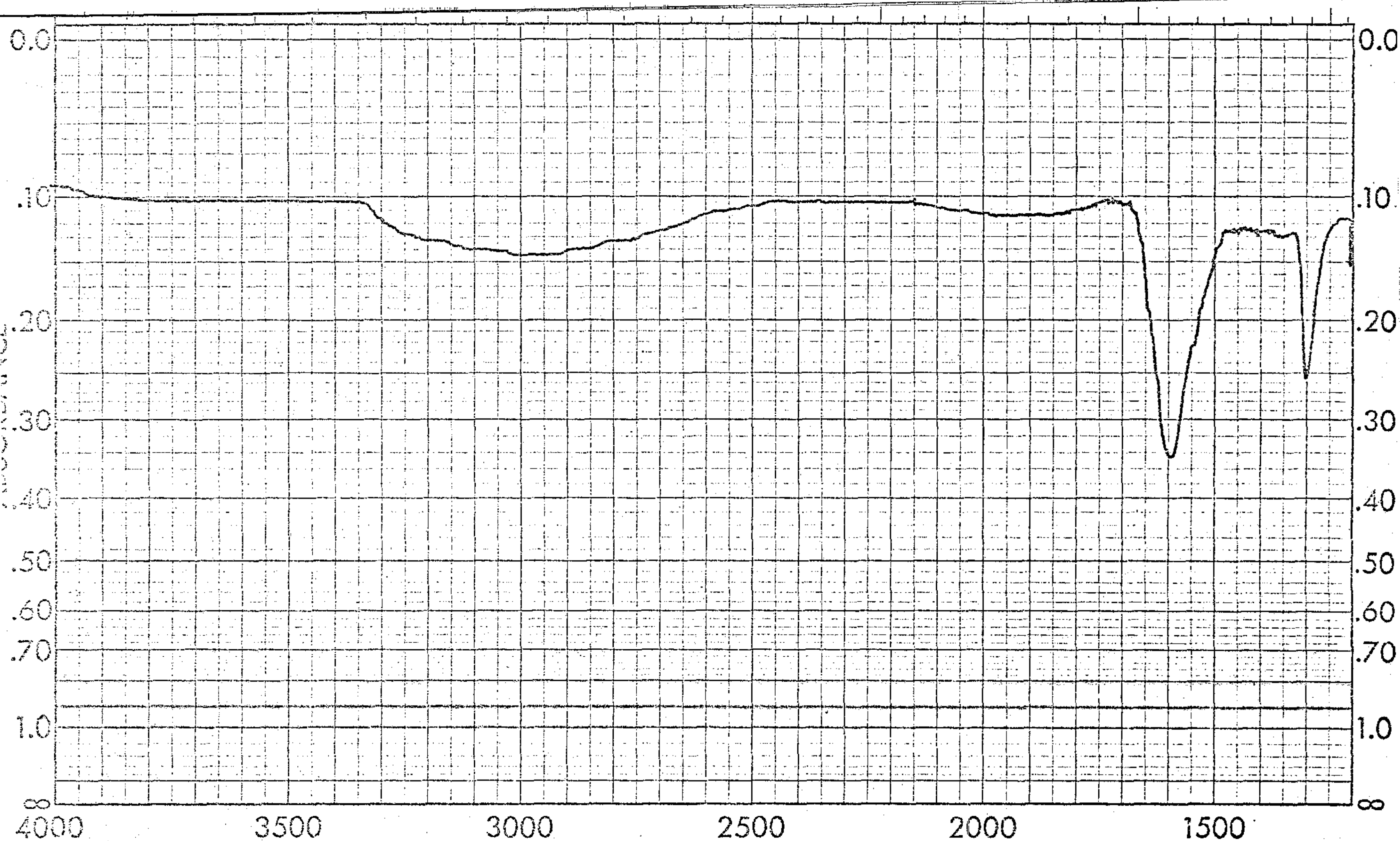
Spectrum No. 94: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



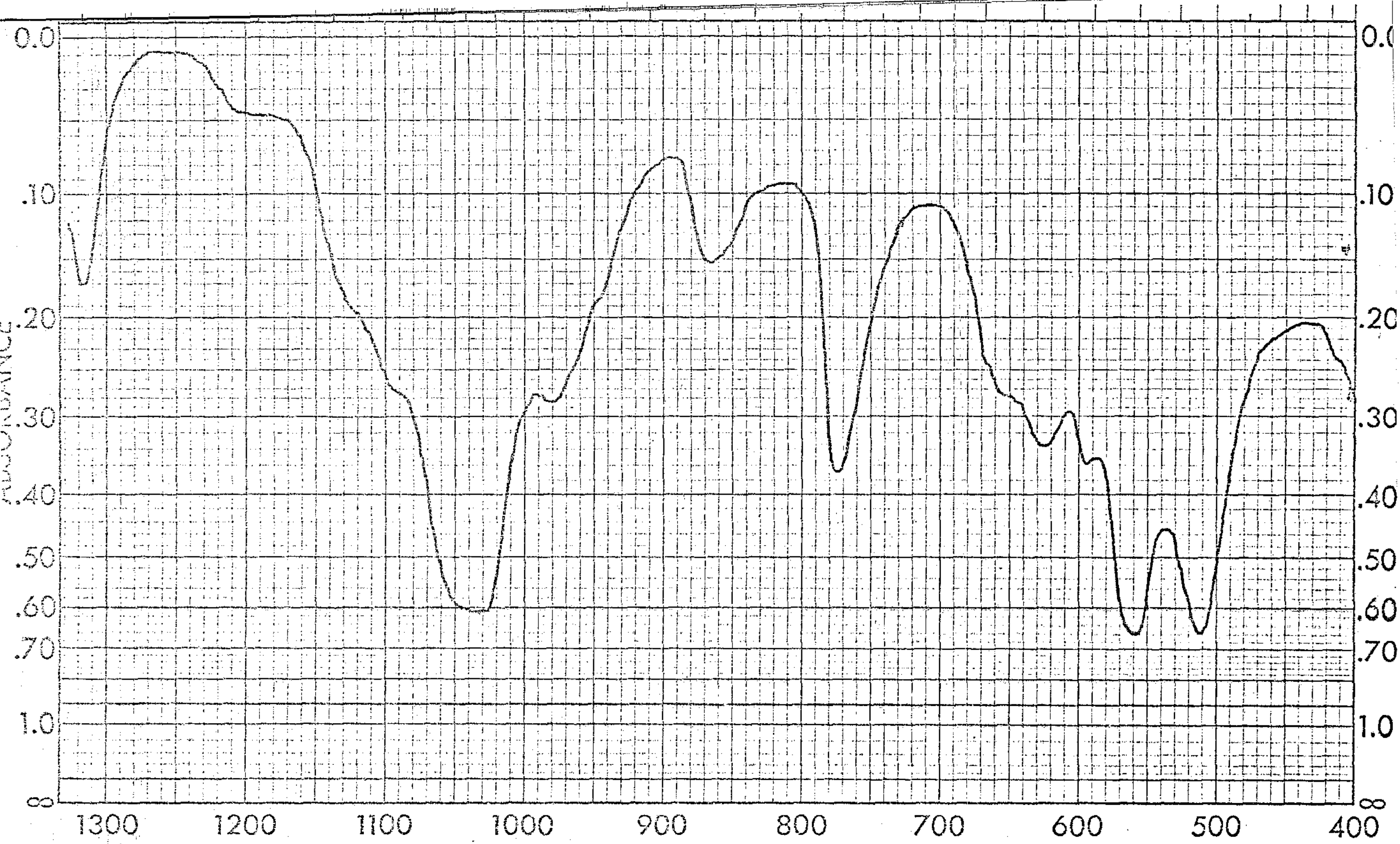
Spectrum No. 95: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, and 25% Magnesium Phosphate,



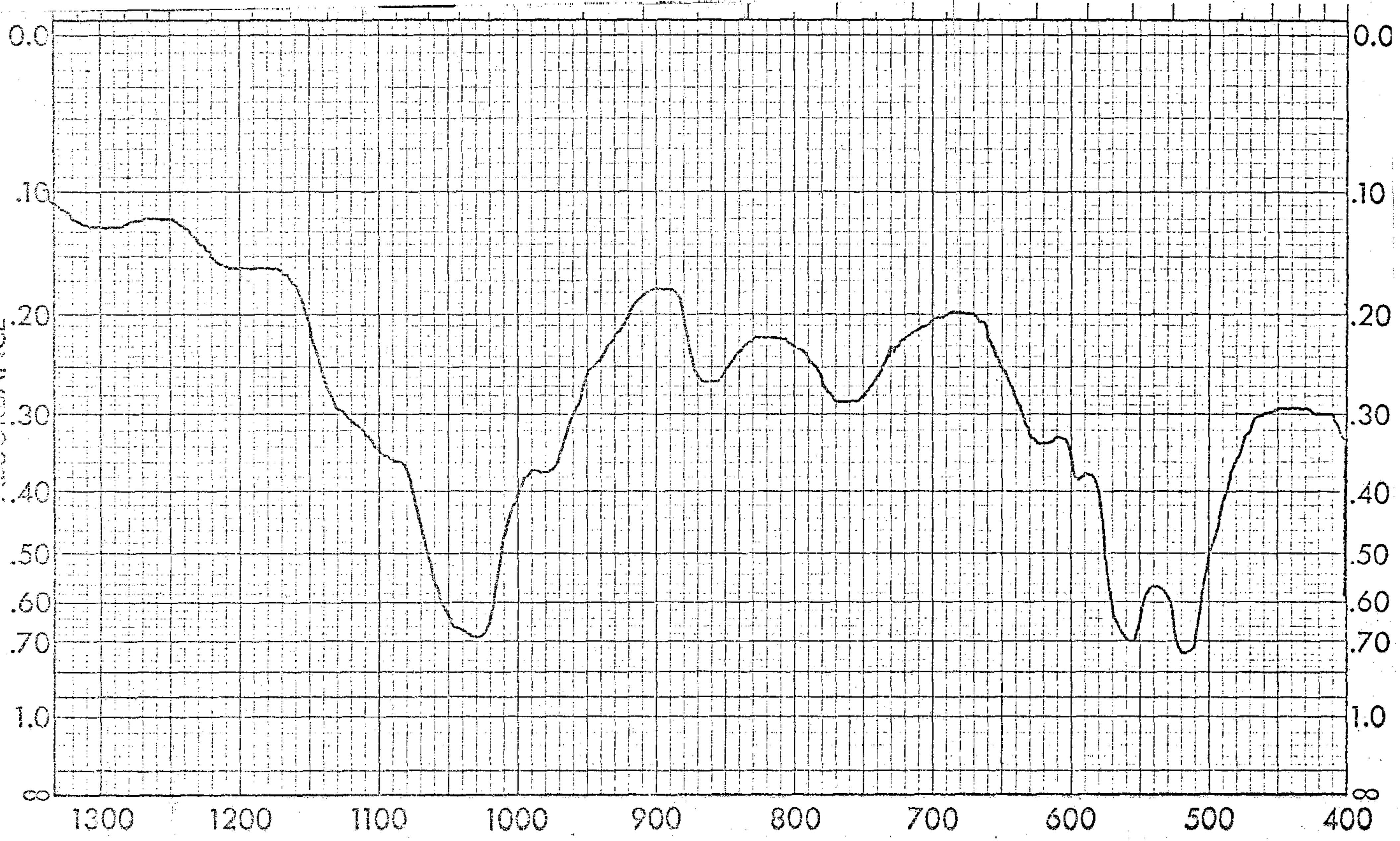
Spectrum No. 95: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, and 25% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



Spectrum No. 96: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ by A.T.R.



Spectrum No. 96: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ by A.T.R.



Spectrum No. 97: 50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ by A.T.R.

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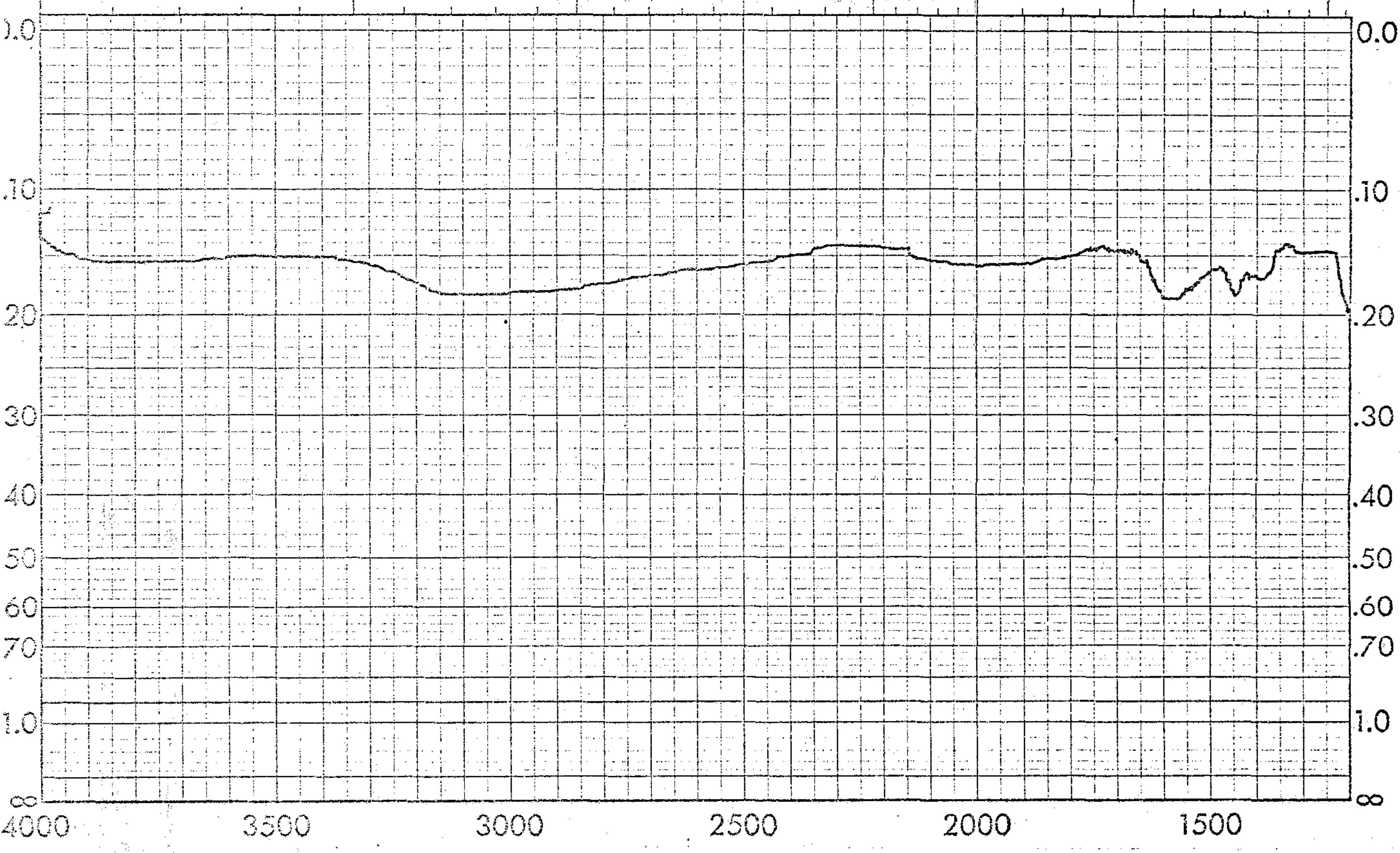
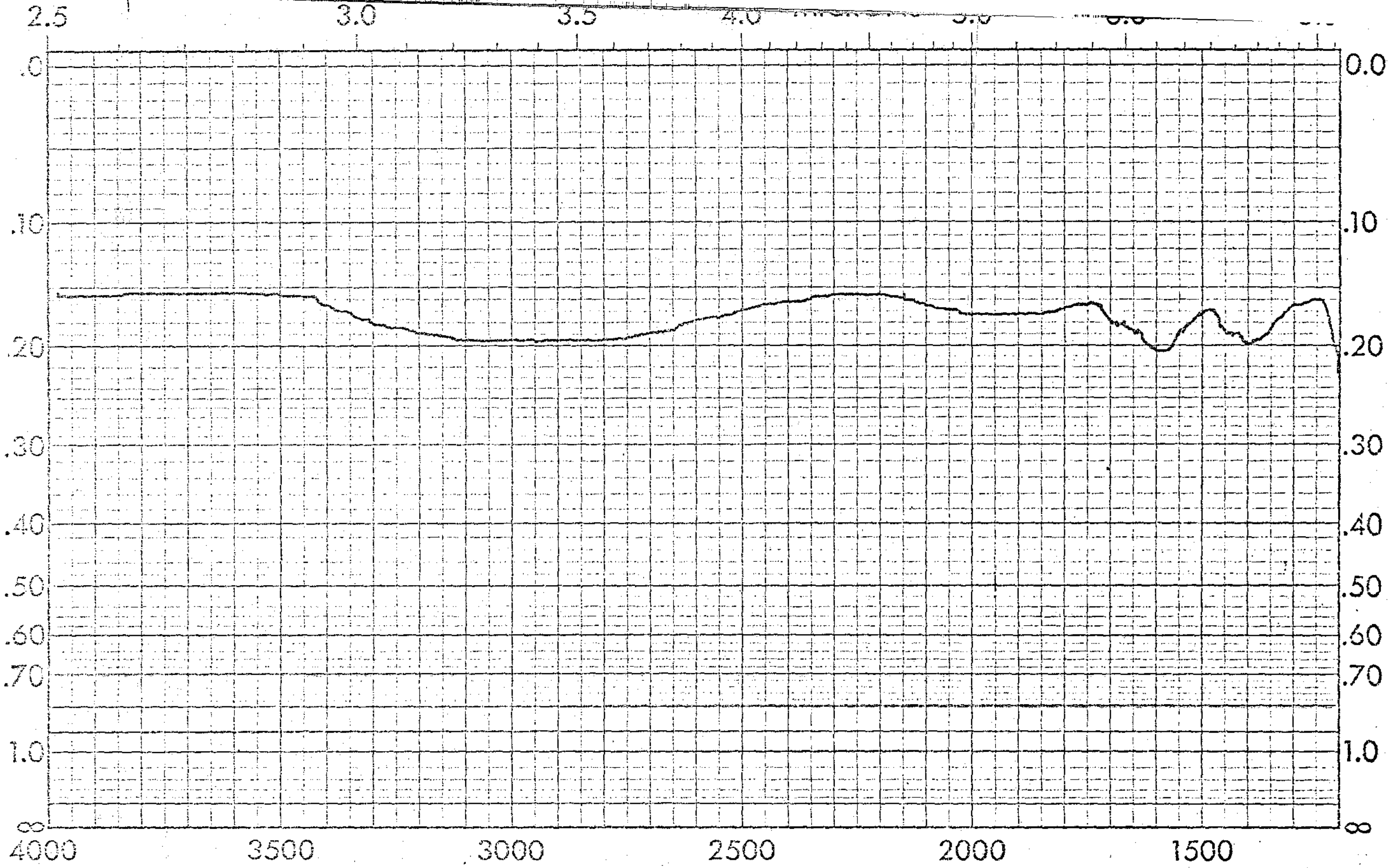
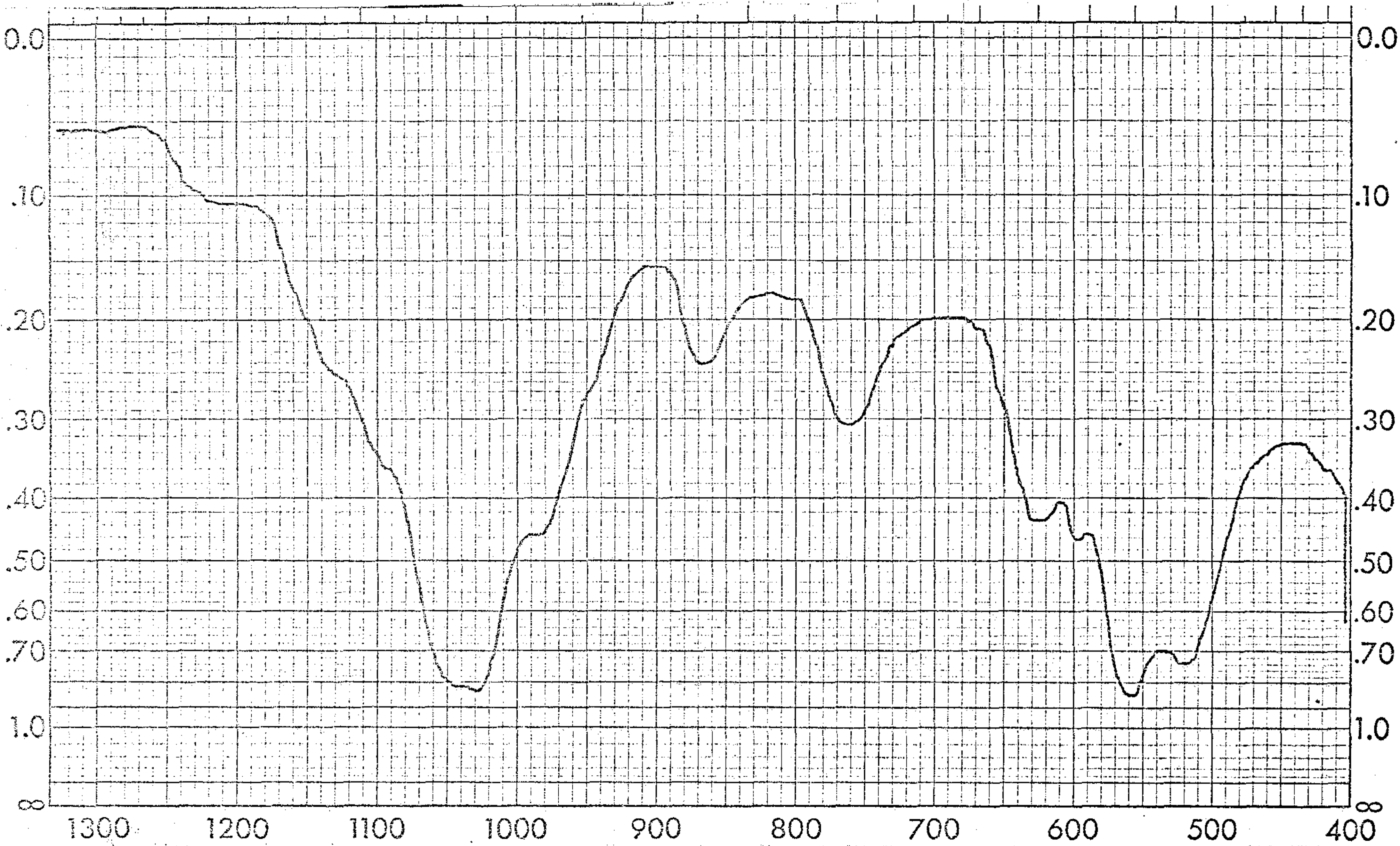


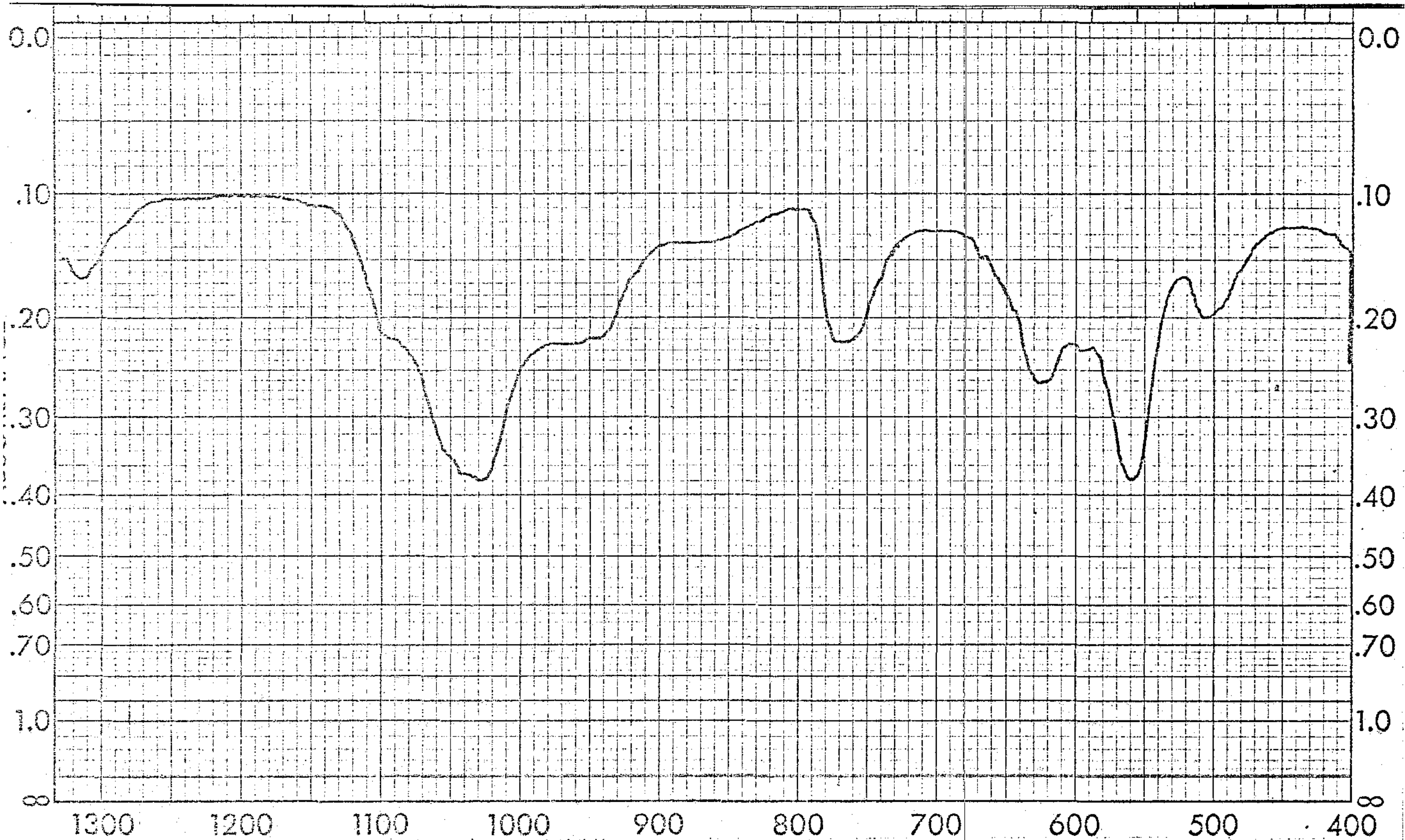
Spectrum No. 97: 50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ by A.T.R.



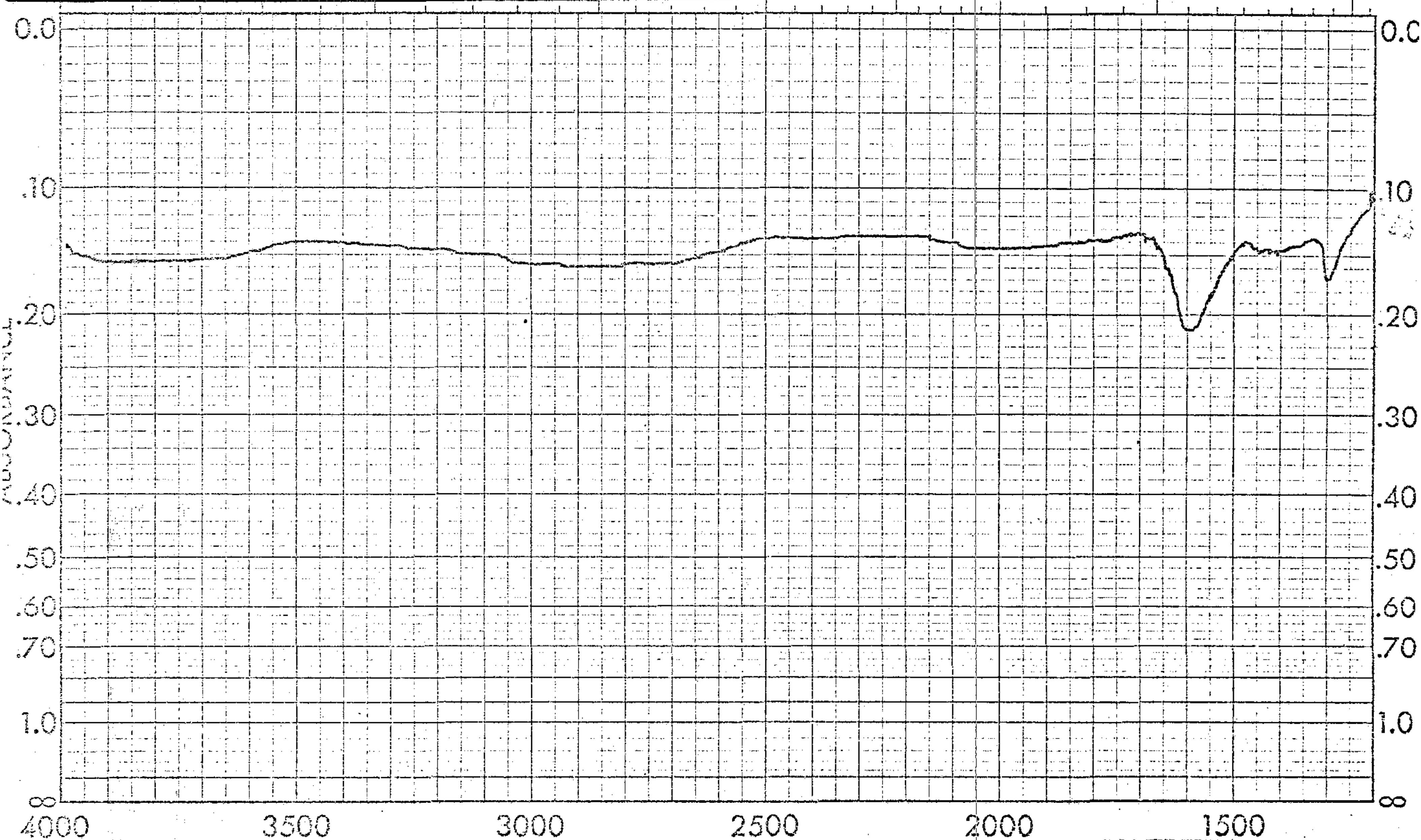
Spectrum No. 98: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate,



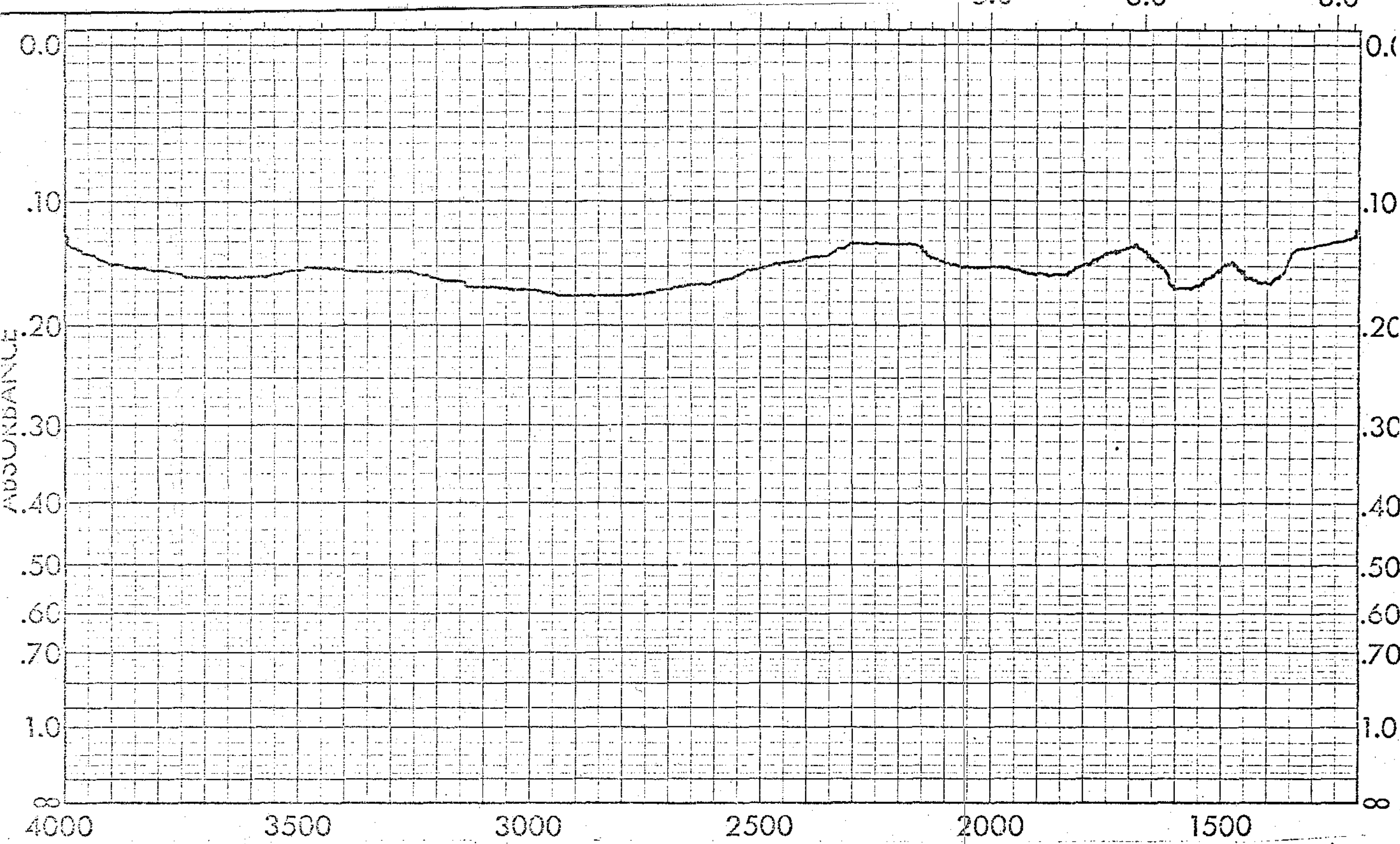
Spectrum No. 98: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



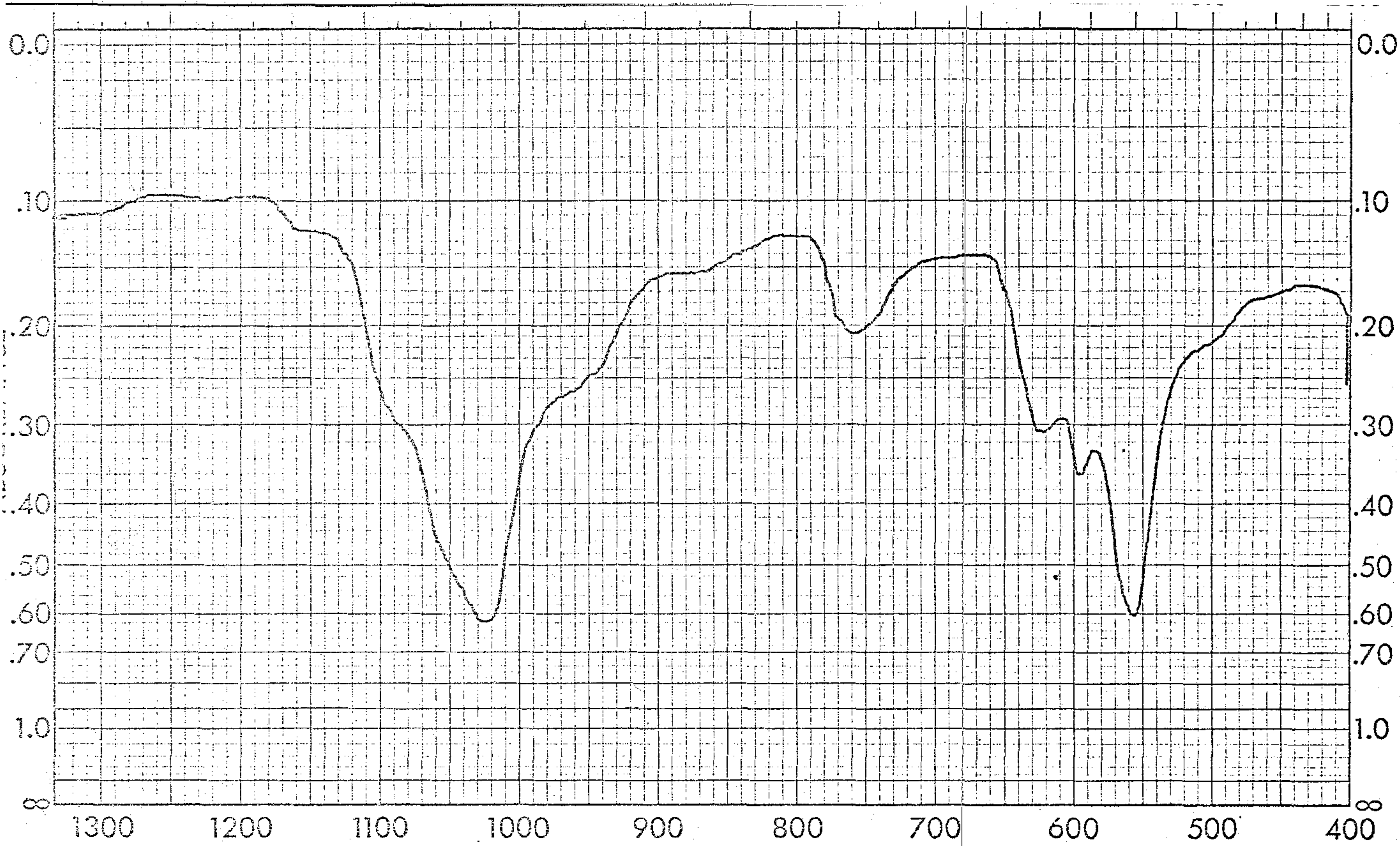
Spectrum No. 99: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ by A.T.R.



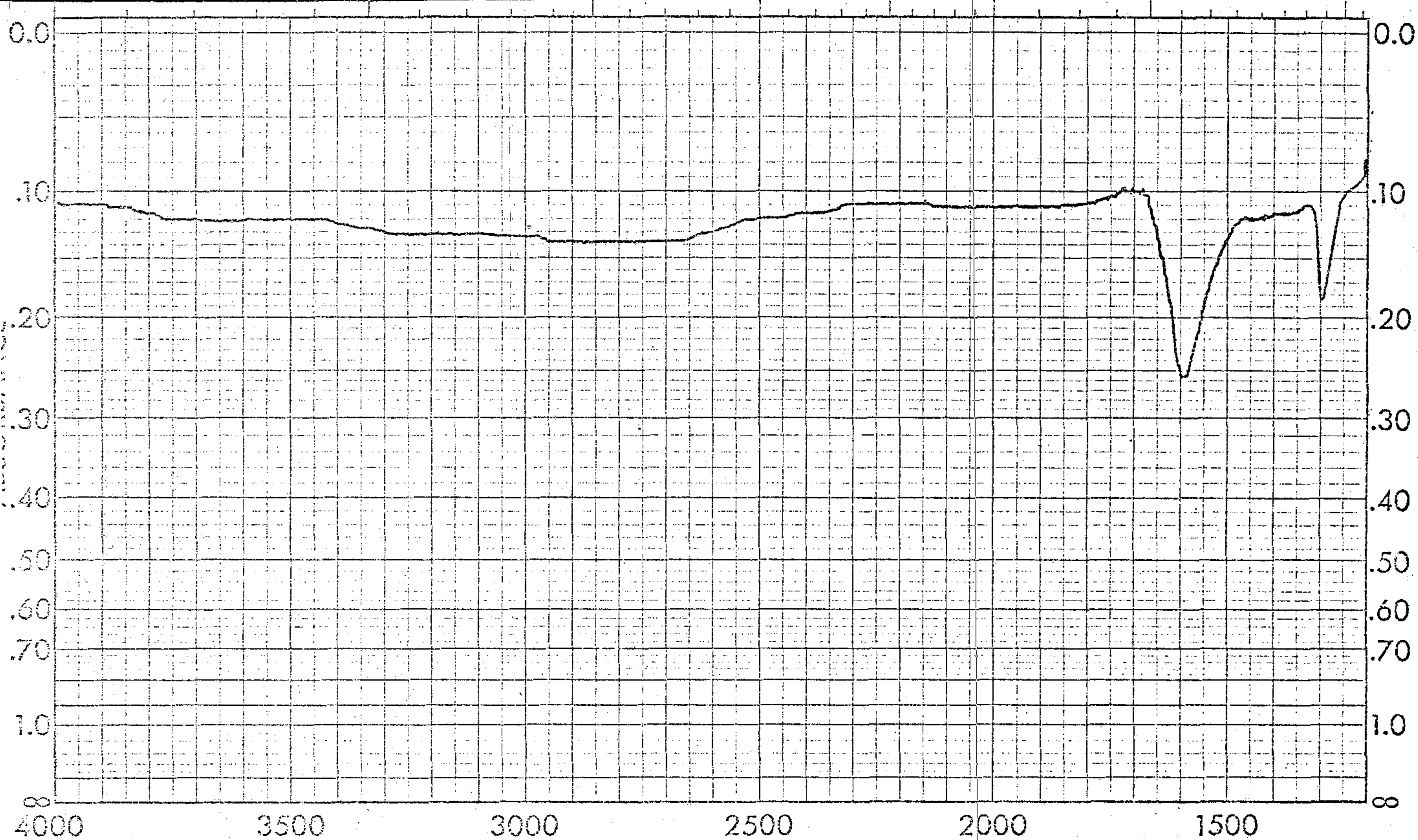
Spectrum No. 99: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$ by A.T.R.



Spectrum No. 100: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ by A.T.R.

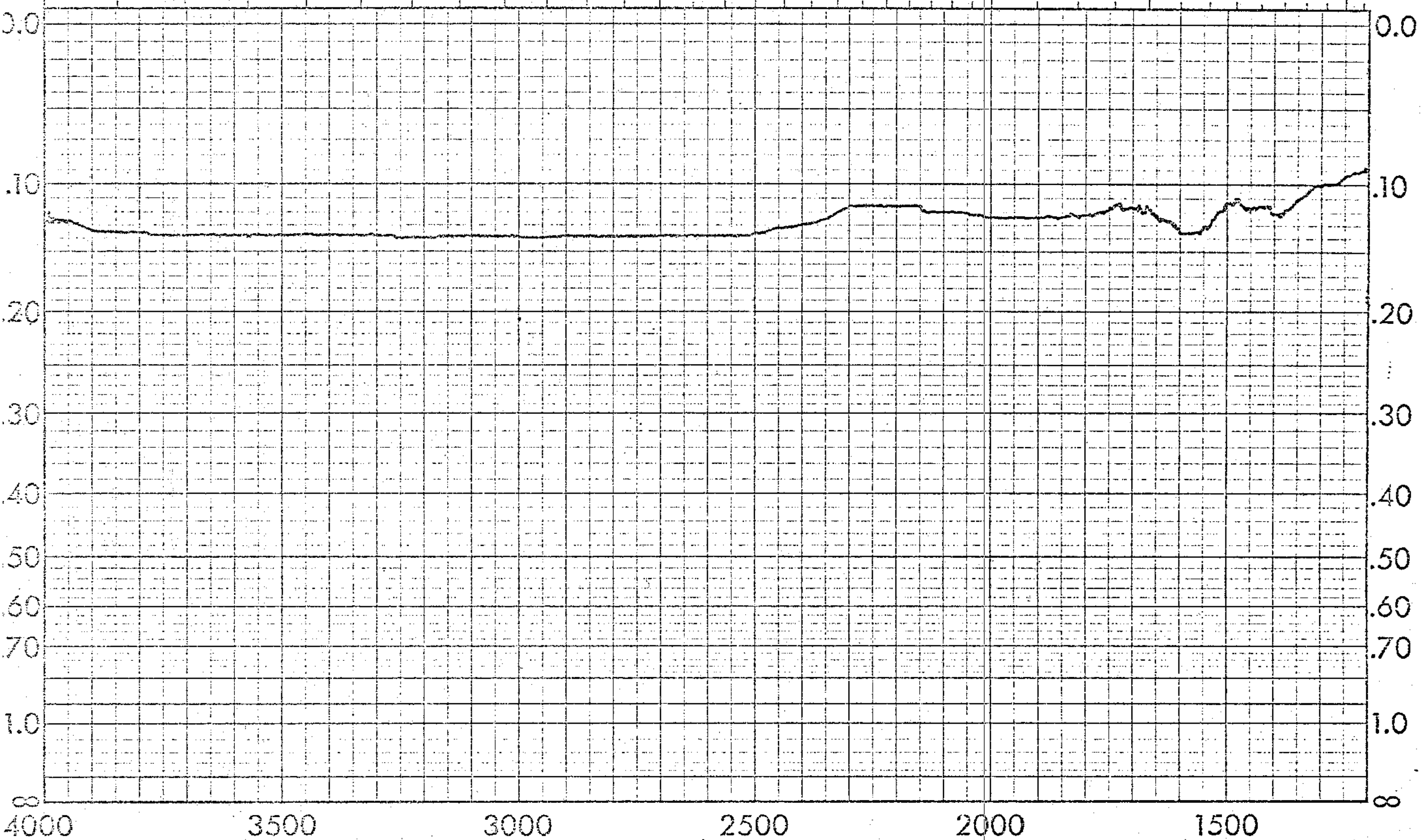


Spectrum No. 100: 50% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ by A.T.R.

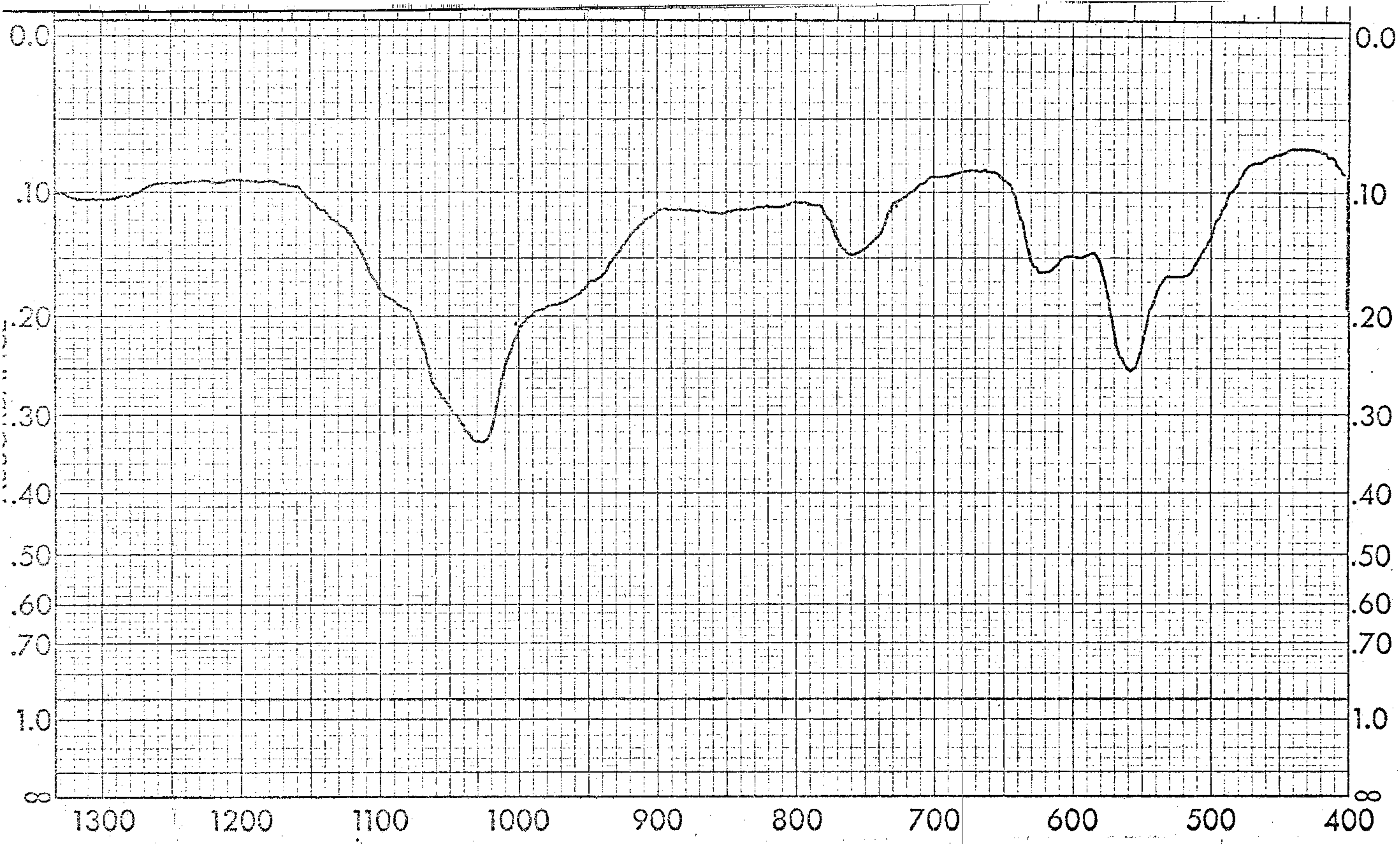


Spectrum No. 101: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, and 25% Magnesium Phosphate, $MgHPO_4$ by A.T.R.

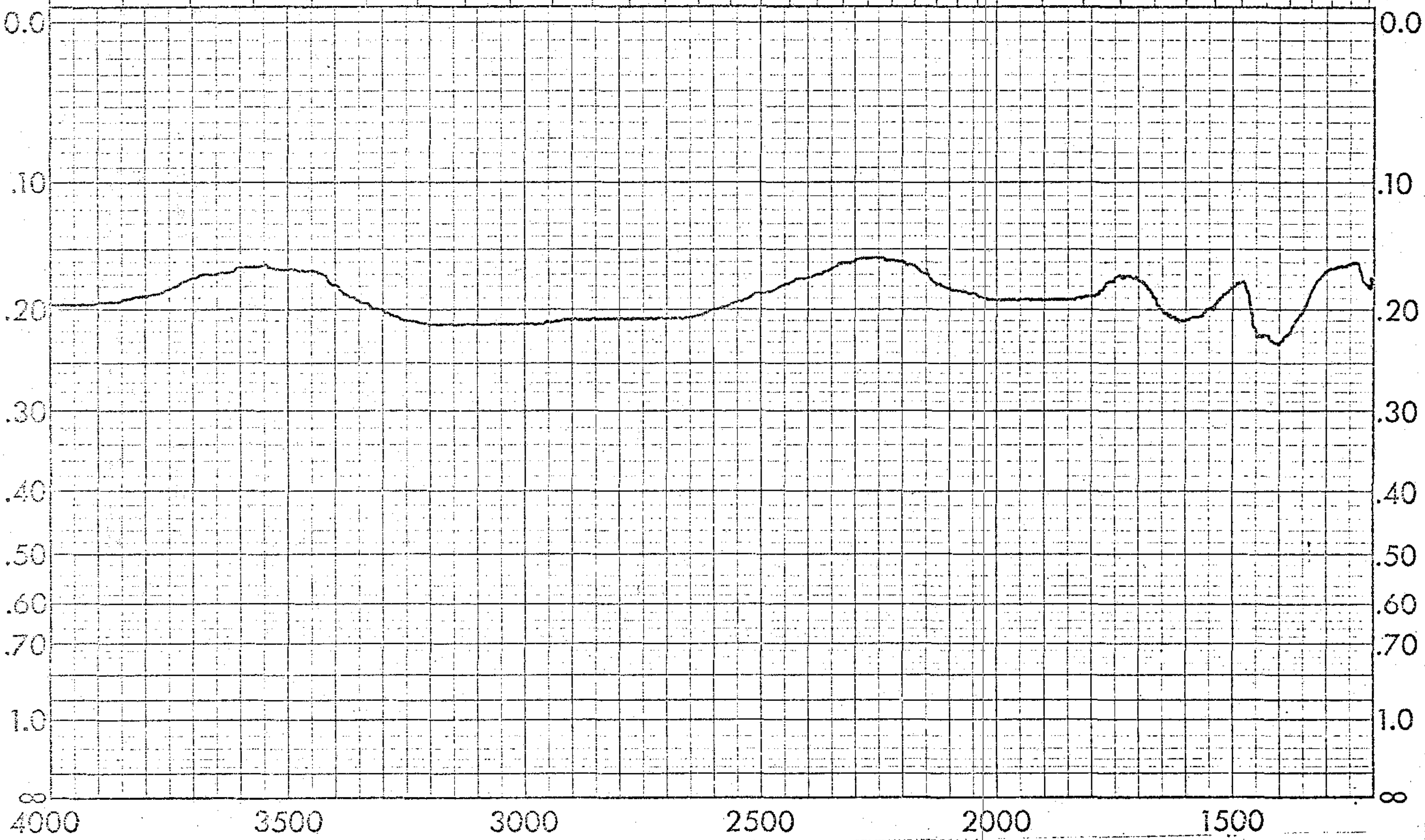
Spectrum No. 101: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, and 25% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



Spectrum No. 102: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Calcium Hydrogen Phosphate, $CaHPO_4$ by A.T.R.

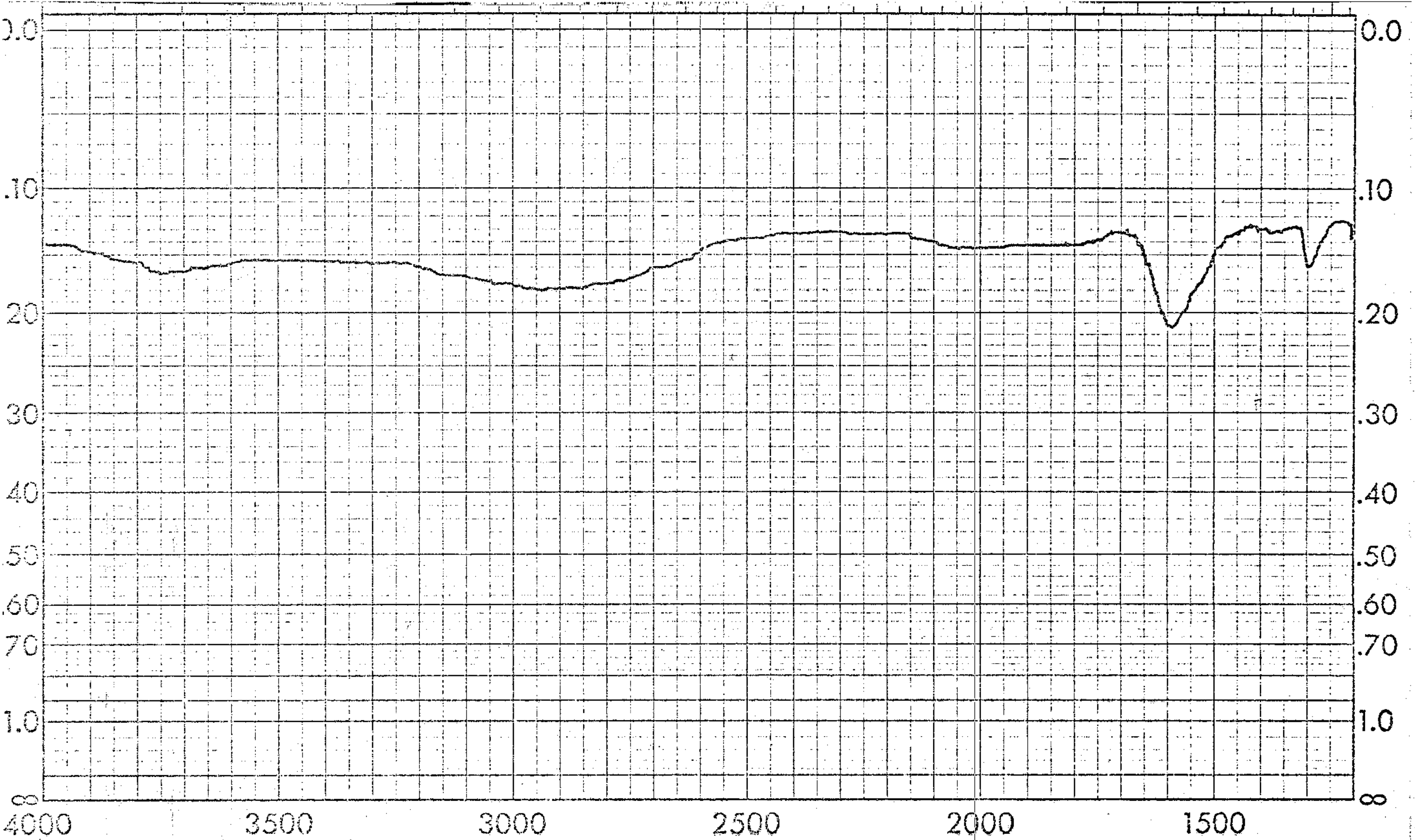


Spectrum No. 102: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Calcium Hydrogen Phosphate, $CaHPO_4$ by A.T.R.

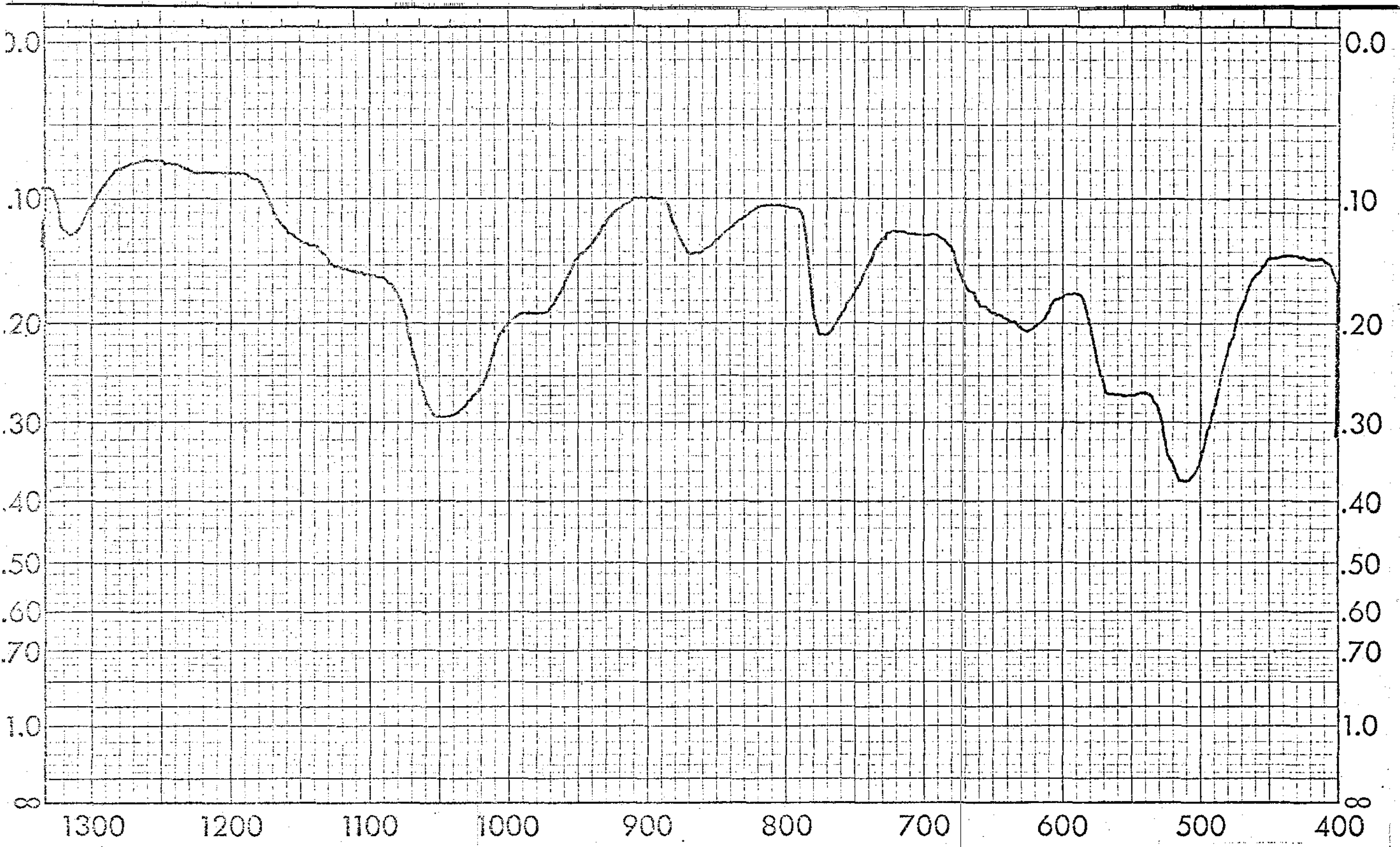


Spectrum No. 103: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Magnesium Phosphate, $MgHPO_4$, and 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$ by A.T.R.

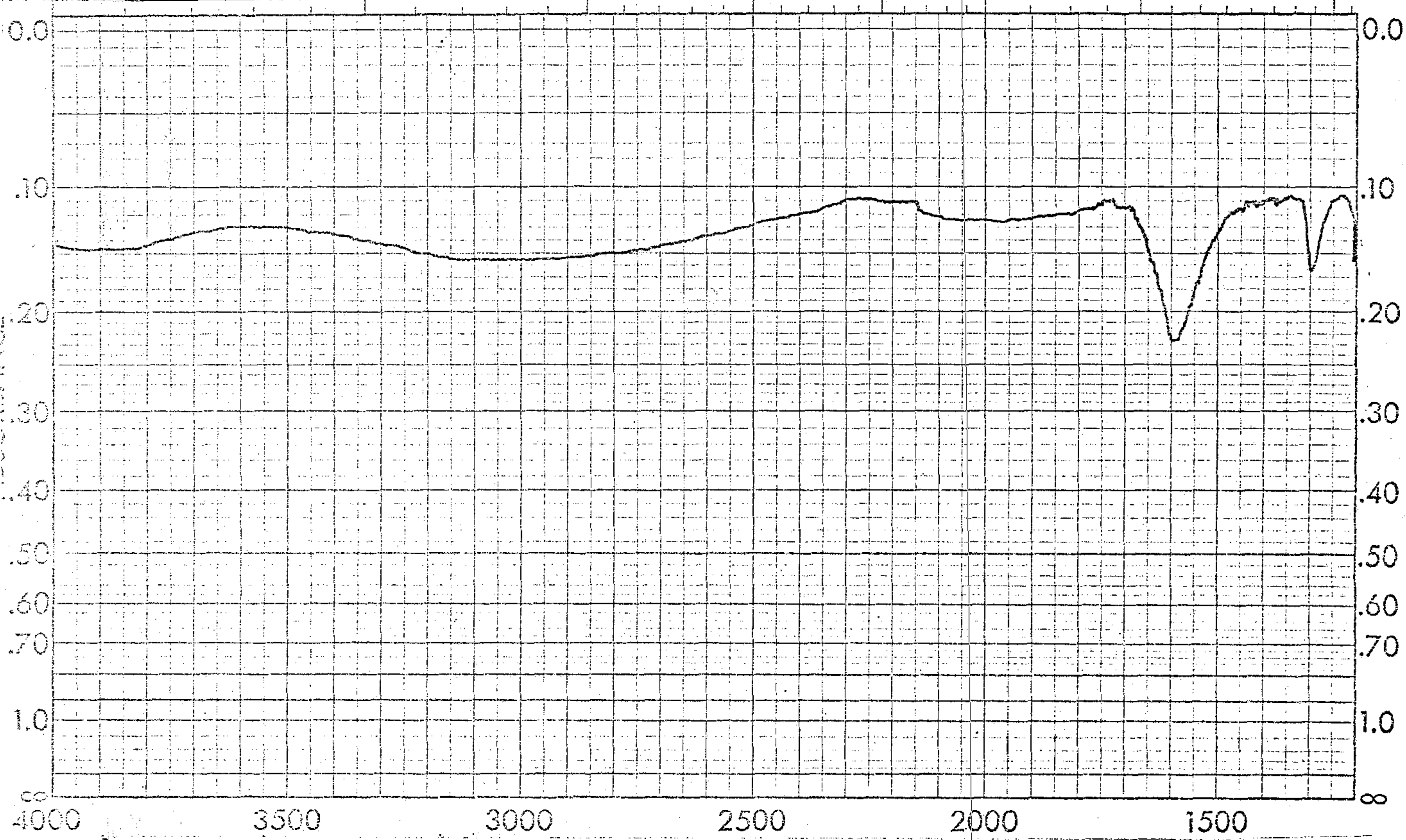
Spectrum No. 103: 50% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Magnesium Phosphate, $MgHPO_4$, and 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$ by A.T.R.



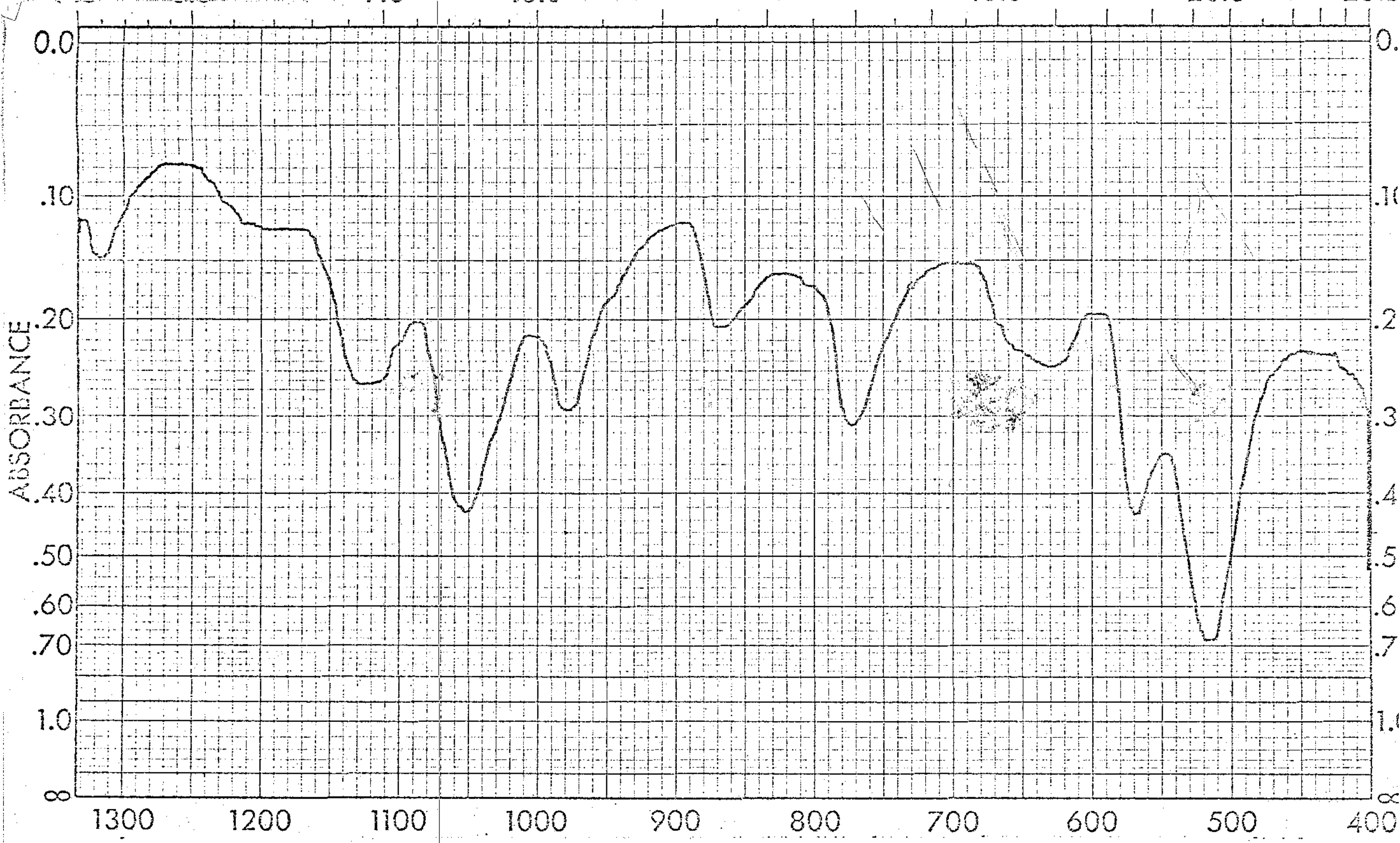
Spectrum No. 104: 25% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate, $MgHPO_4$, by A.T.R.



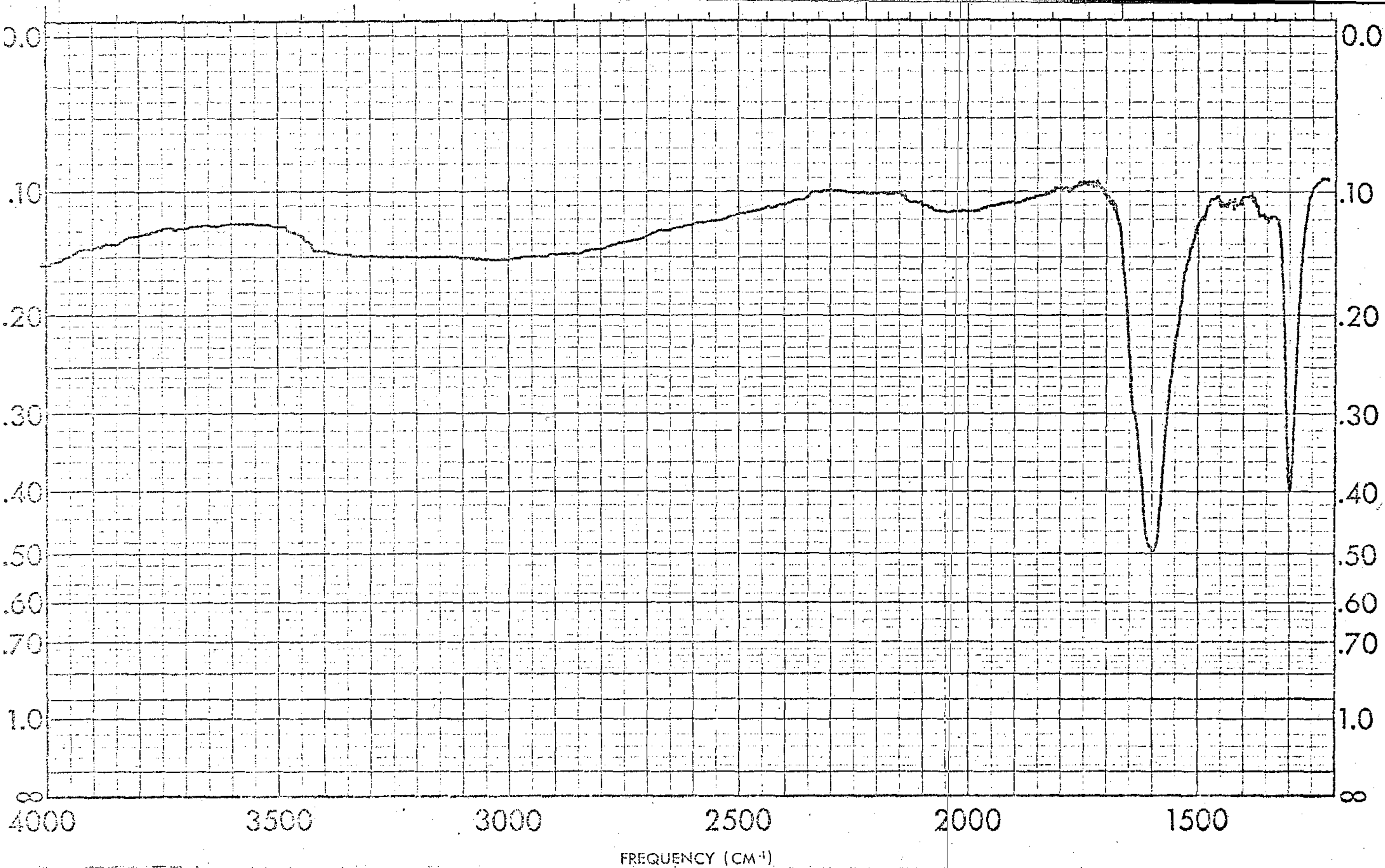
Spectrum No. 104: 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium



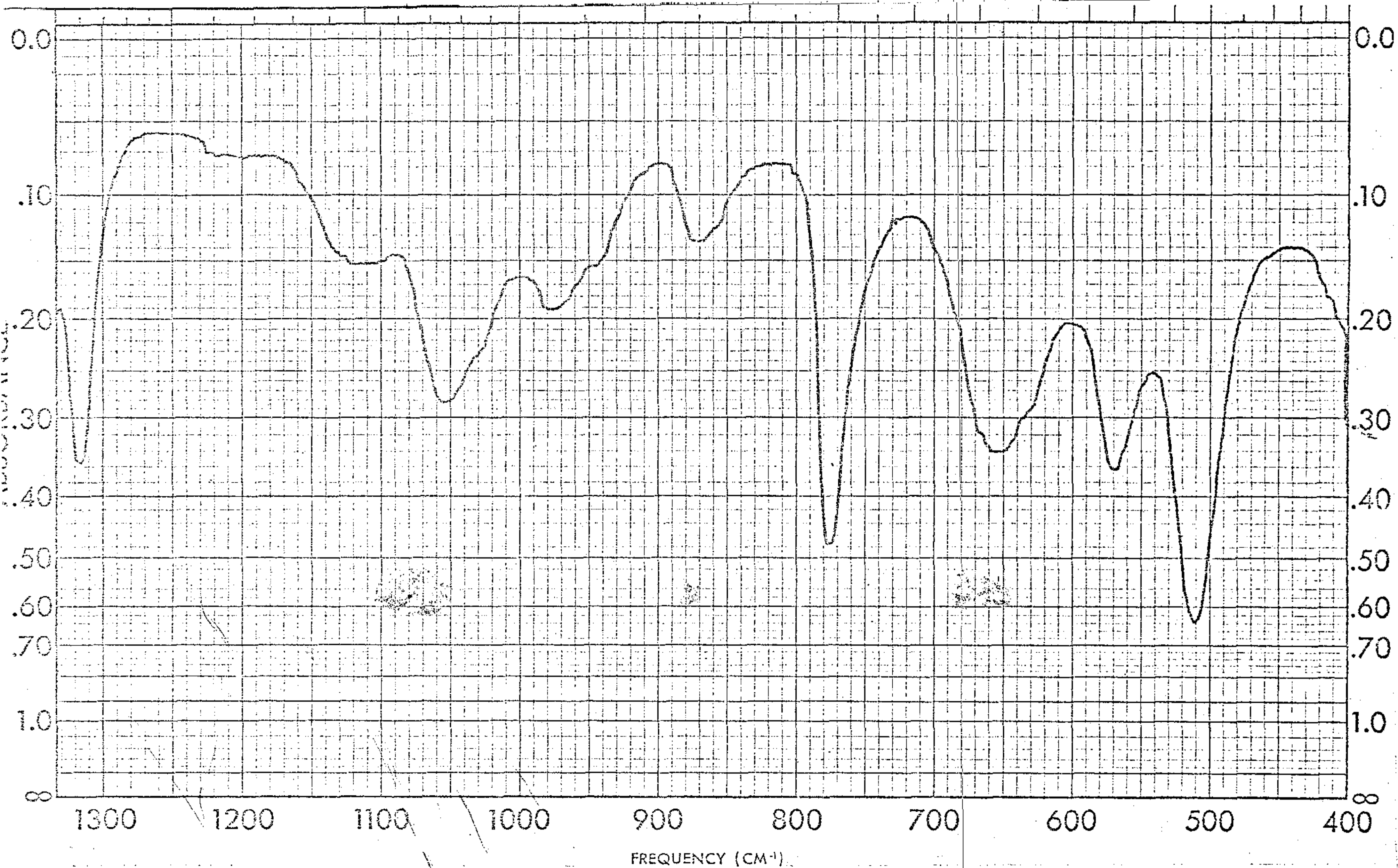
Spectrum No. 105: 50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$ by A.T.R.



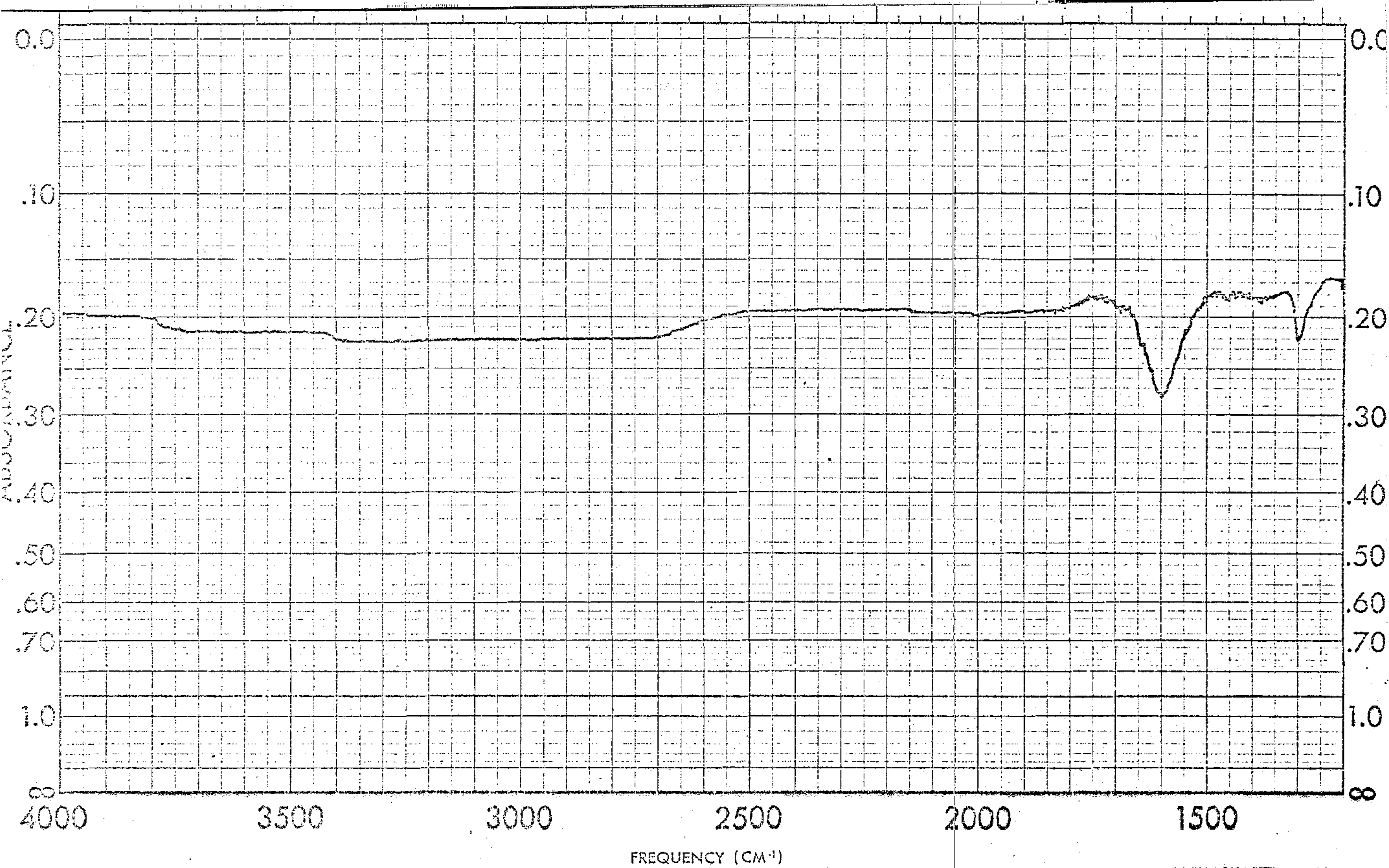
Spectrum No. 105: 50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$ by A.T.R.



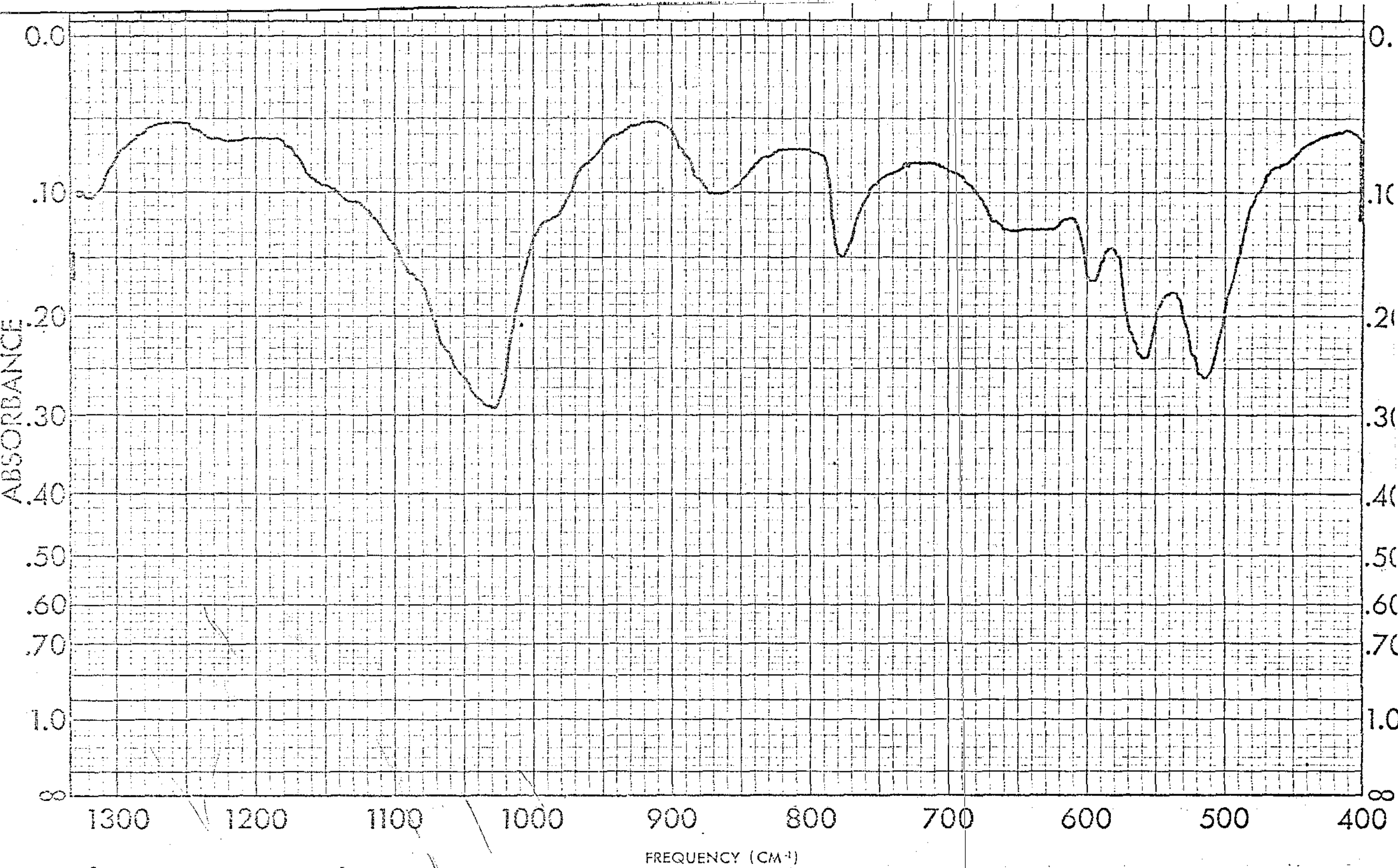
Spectrum No. 106: 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, and 25% Magnesium Ammonium .



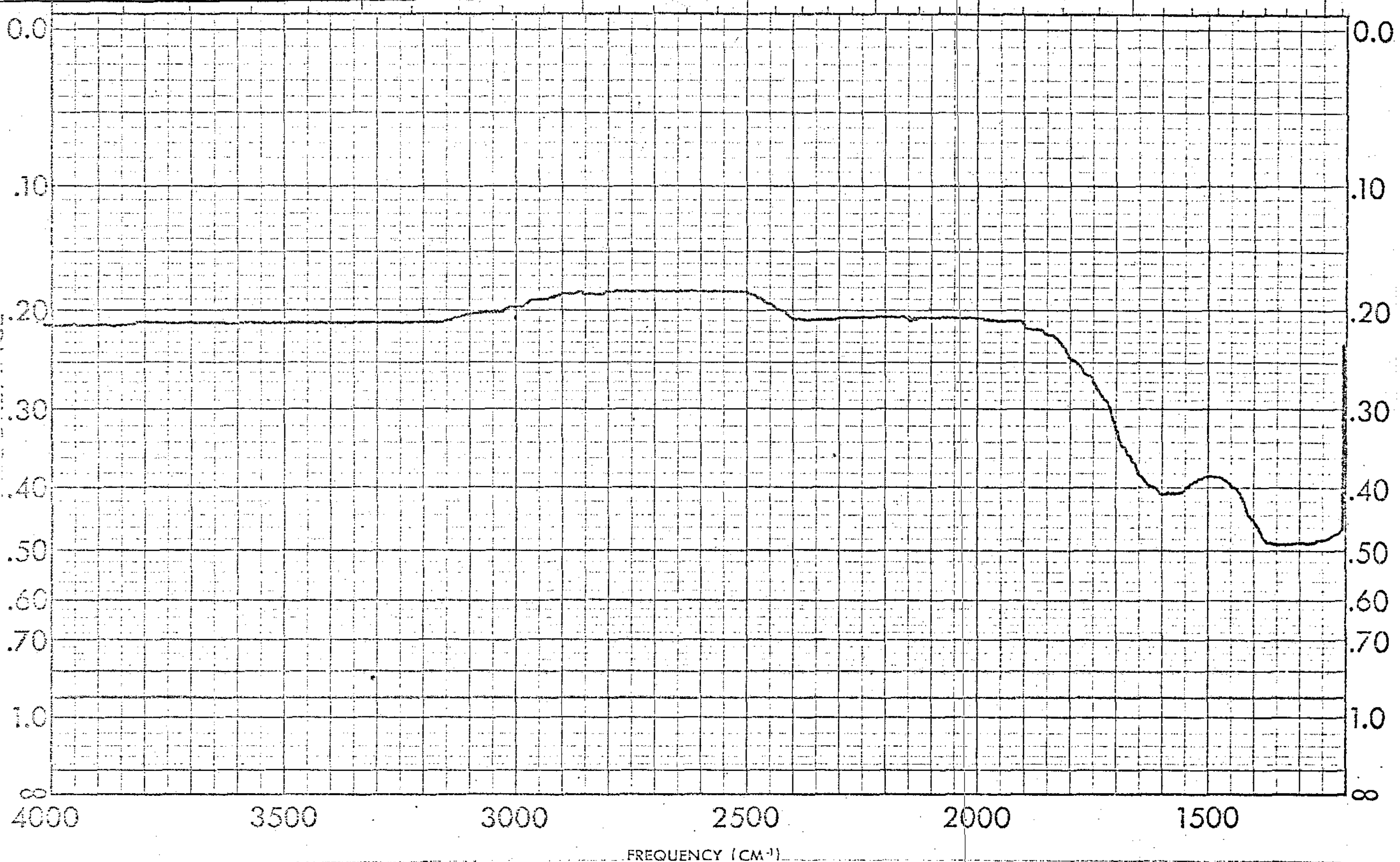
Spectrum No. 106: 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, and 25% Magnesium Ammonium



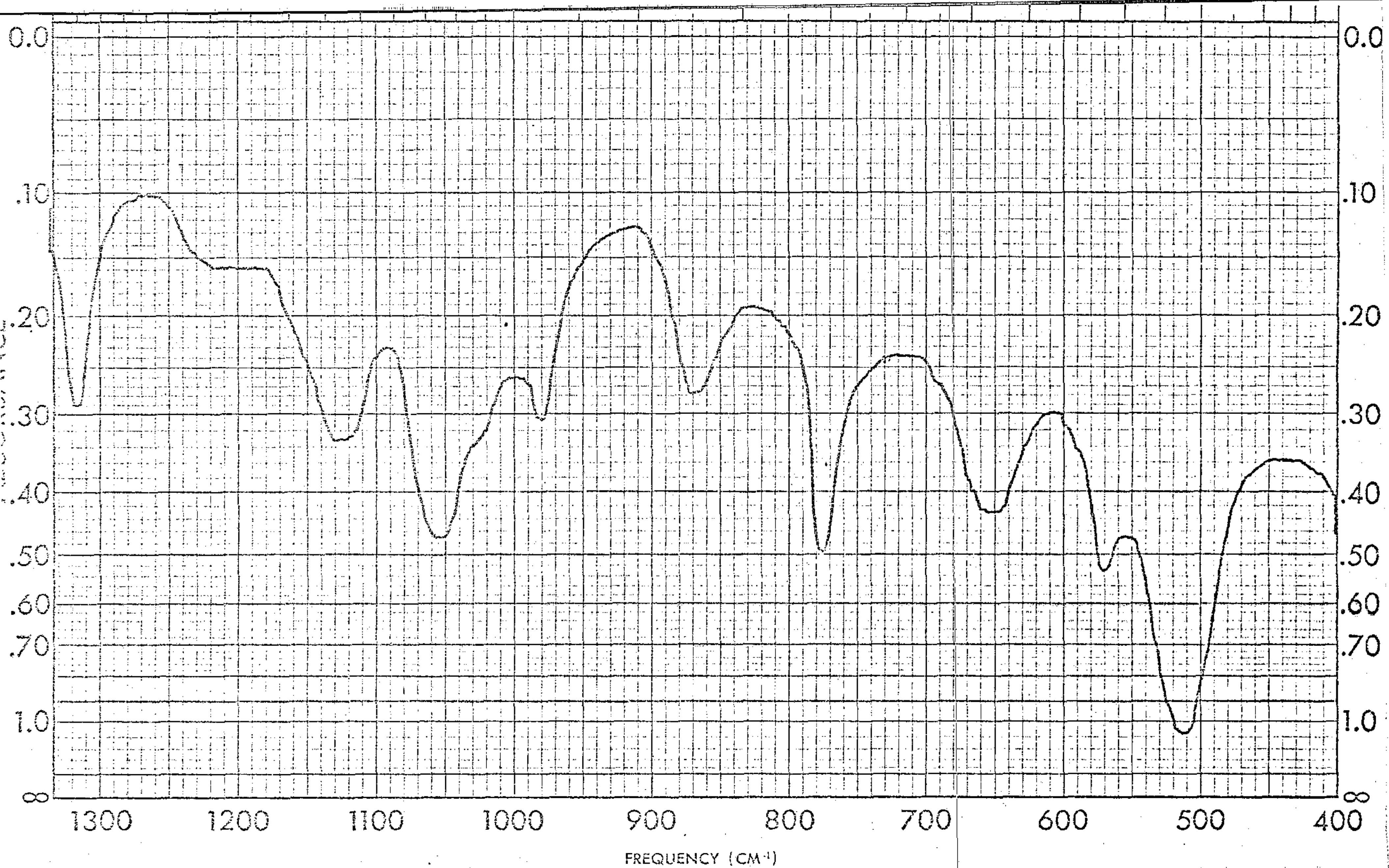
Spectrum No. 107: 25% Calcium Oxalate Monohydrate, $CaC_2O_4 . H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium Phosphate, $MgHPO_4$ by A. T. P.



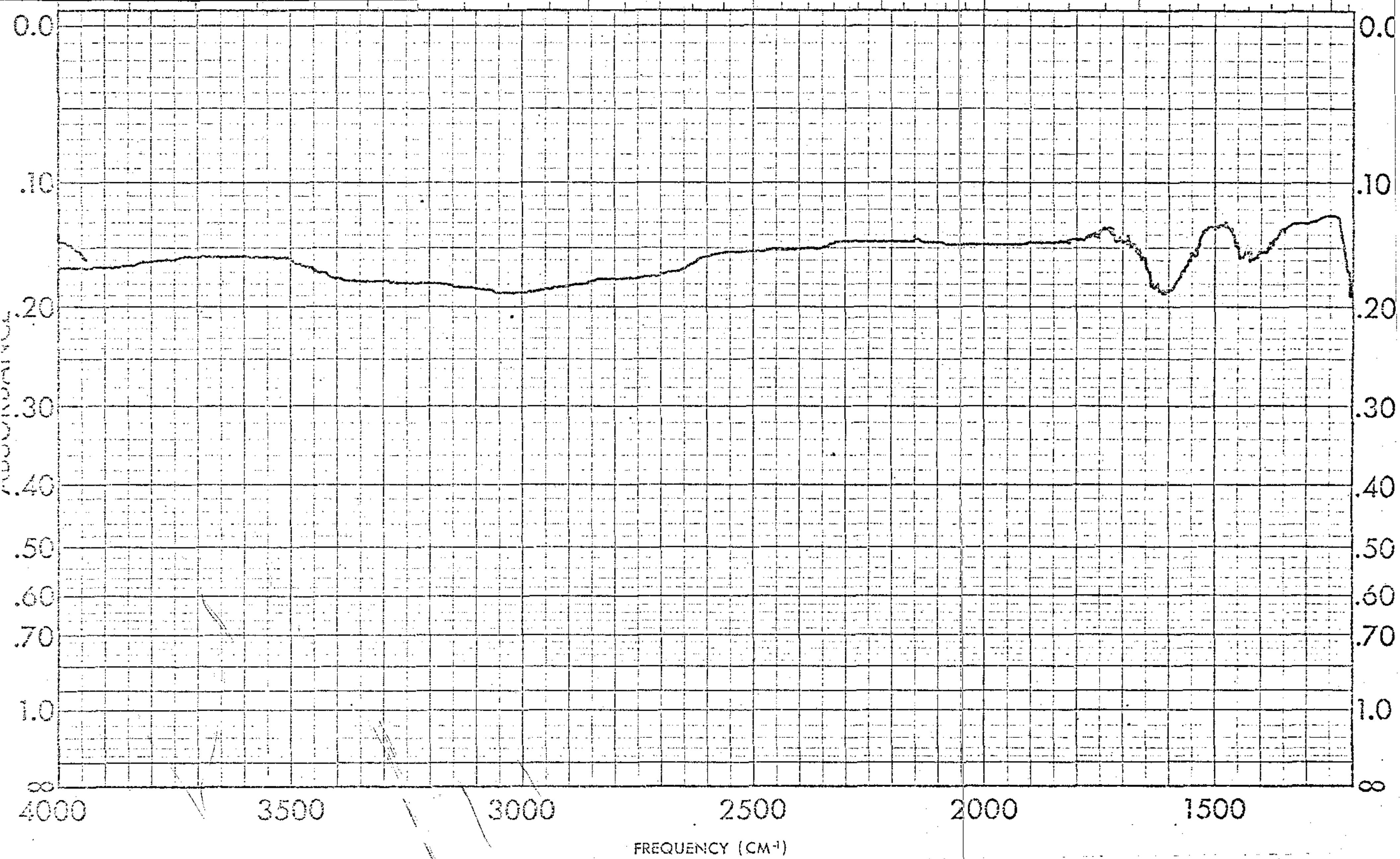
Spectrum No. 107: 25% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium Phosphate $MgHPO_4$ by A.T.R.



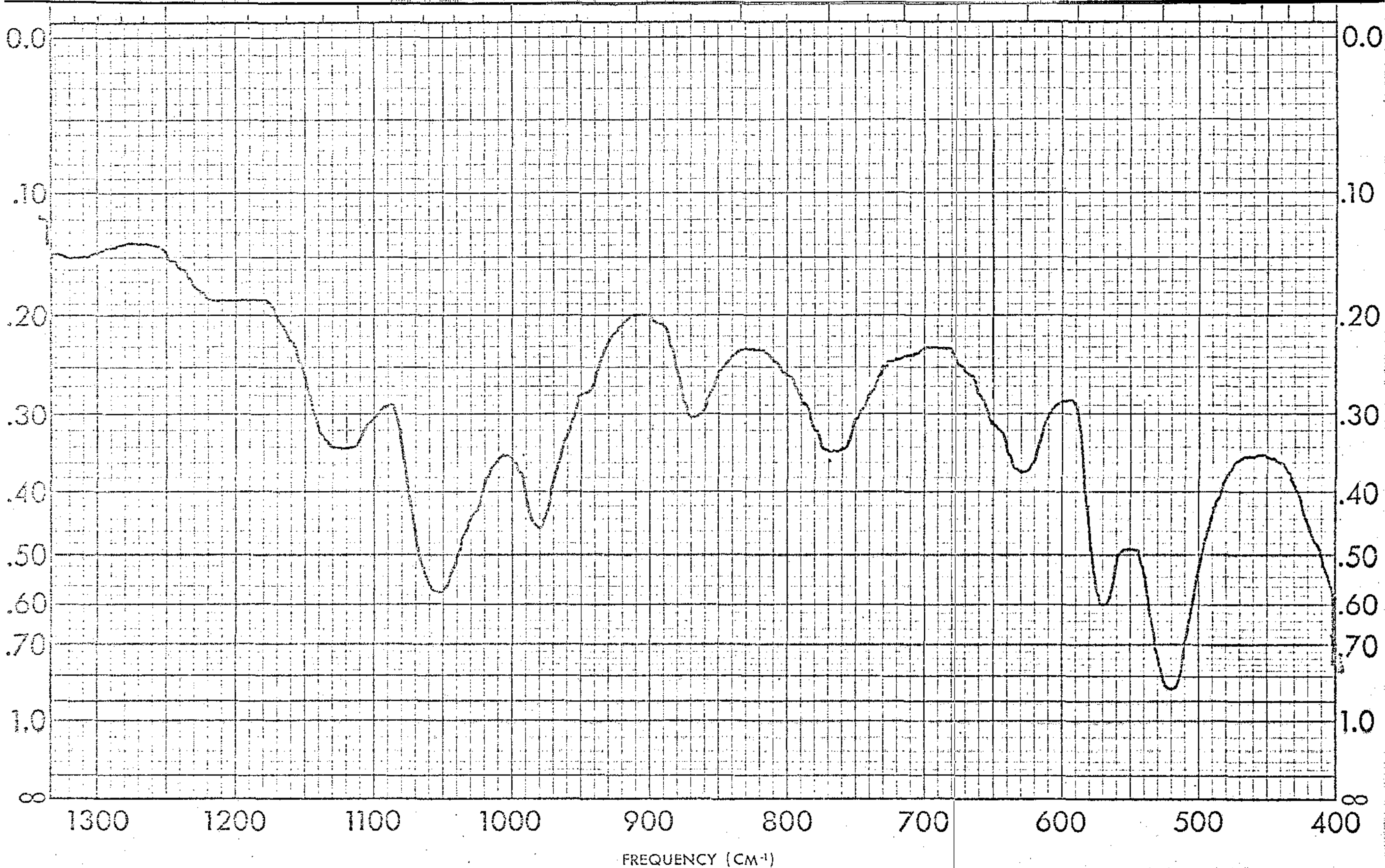
Spectrum No. 108: 50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, and 25% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



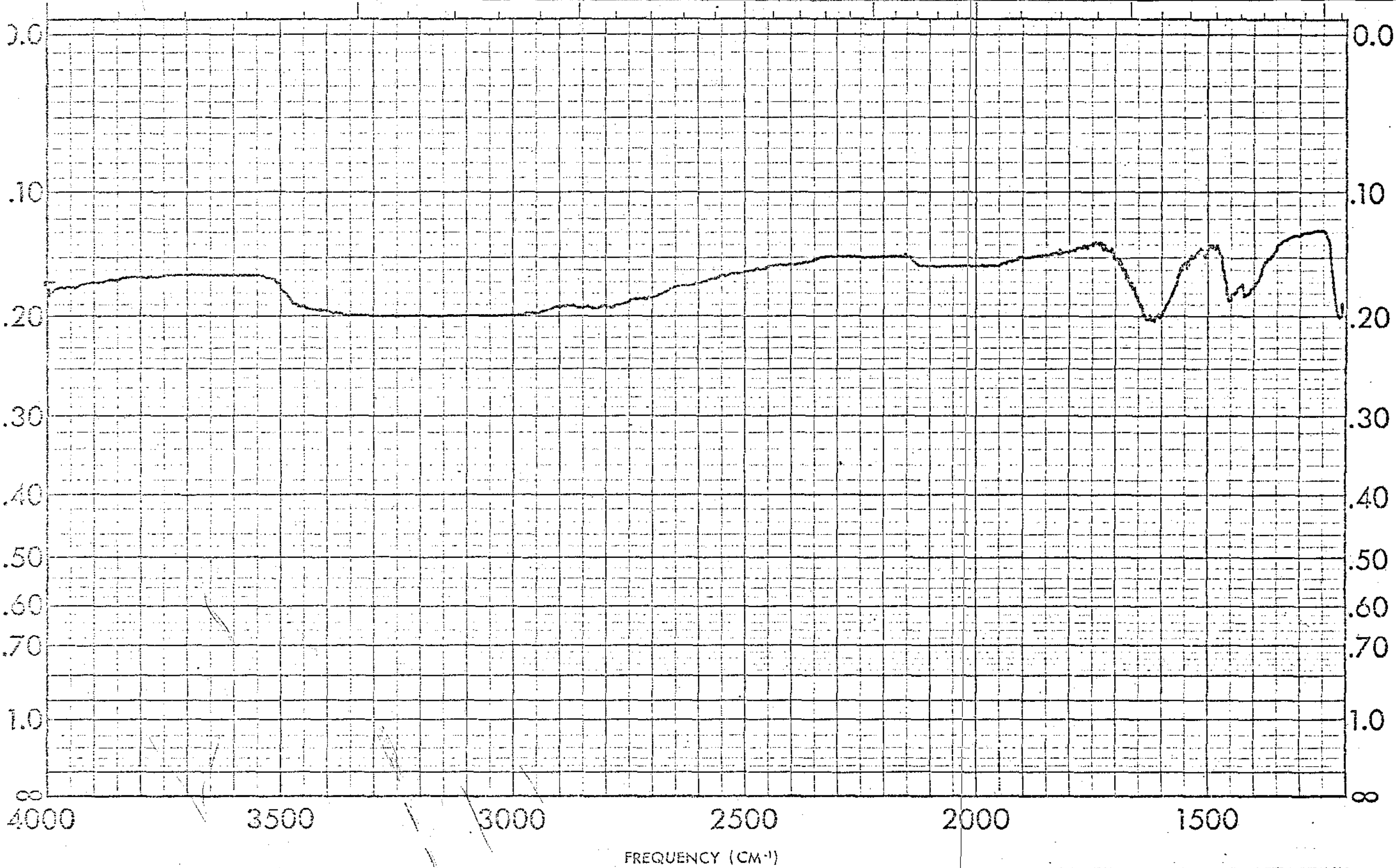
Spectrum No. 108: 50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, and 25% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



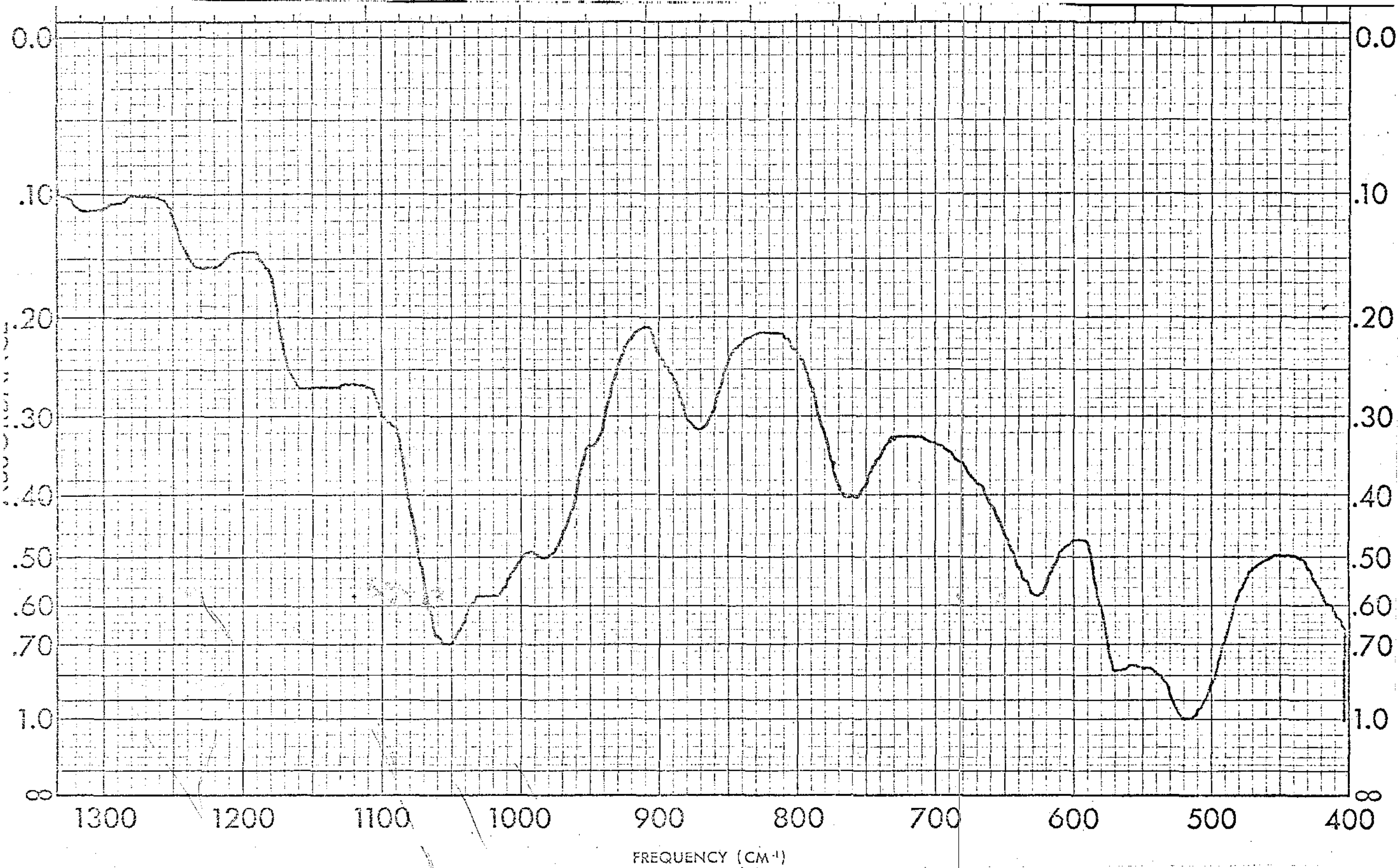
Spectrum No. 109: 50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Phosphate, $MgHPO_4$, and 25% Magnesium Ammonium Phosphate,



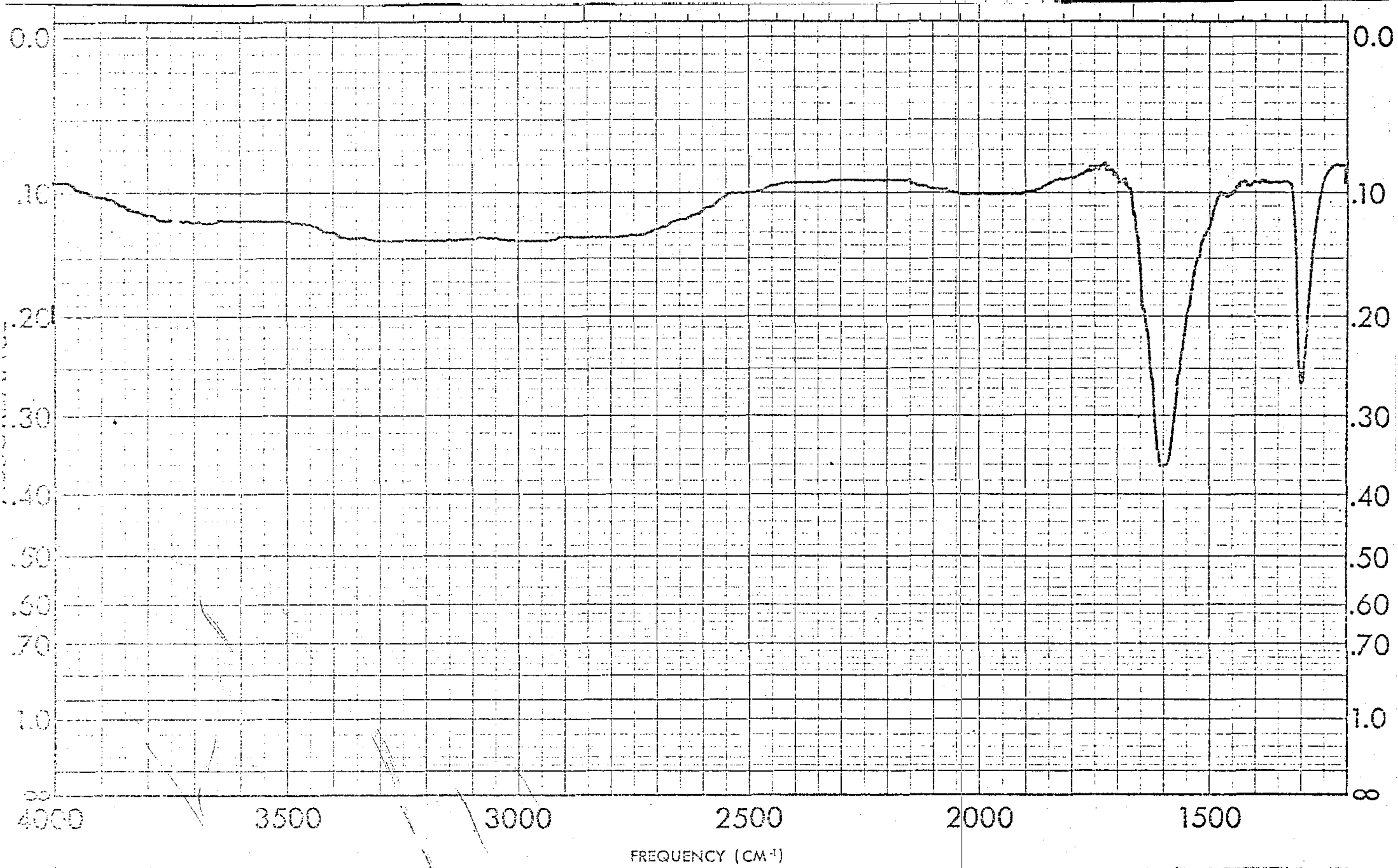
Spectrum No. 109: 50% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Magnesium Phosphate, MgHPO , and 25% Magnesium Ammonium Phosphate,



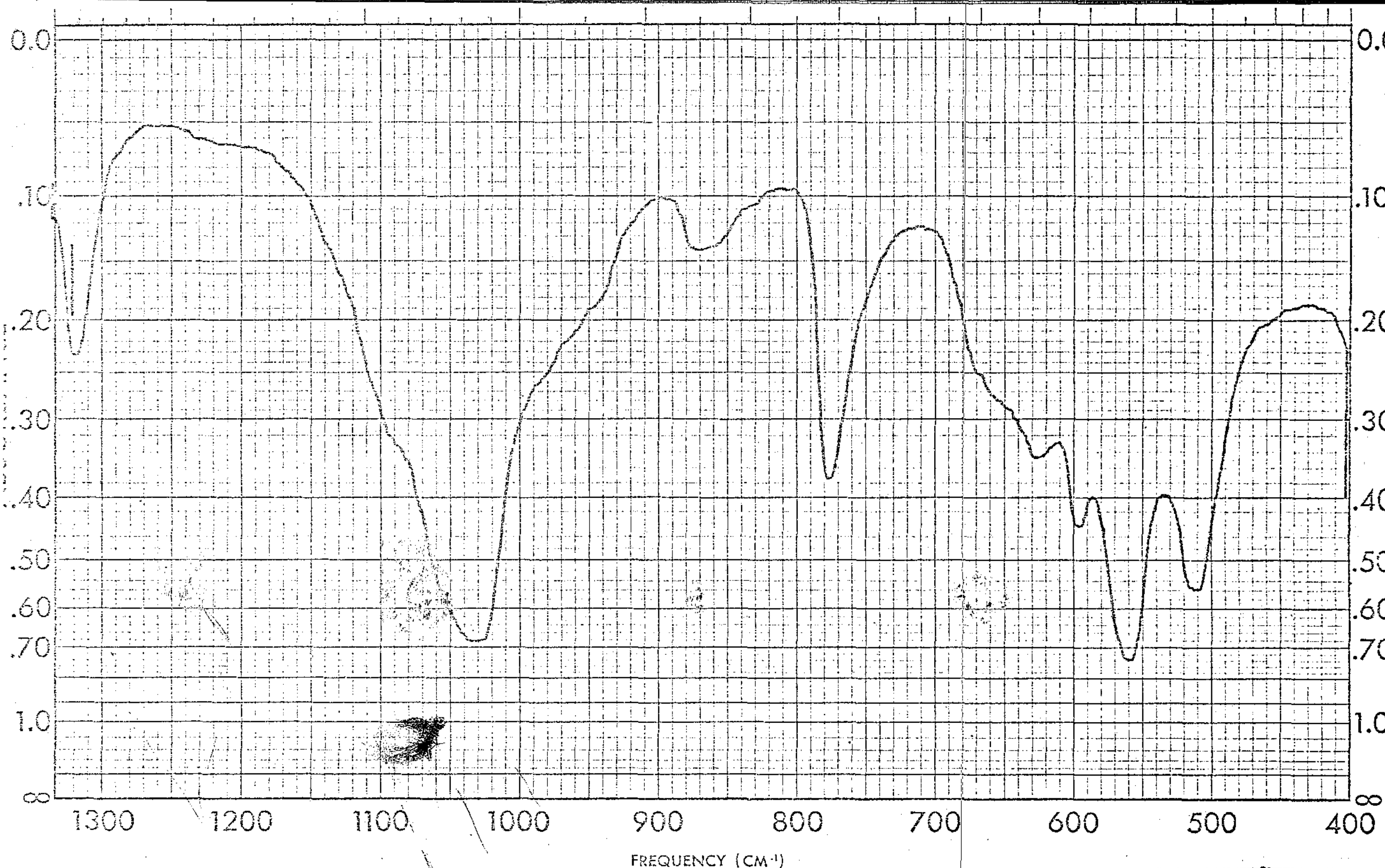
Spectrum No. 110: 50% Magnesium Phosphate, $MgHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Hydrogen Phosphate,



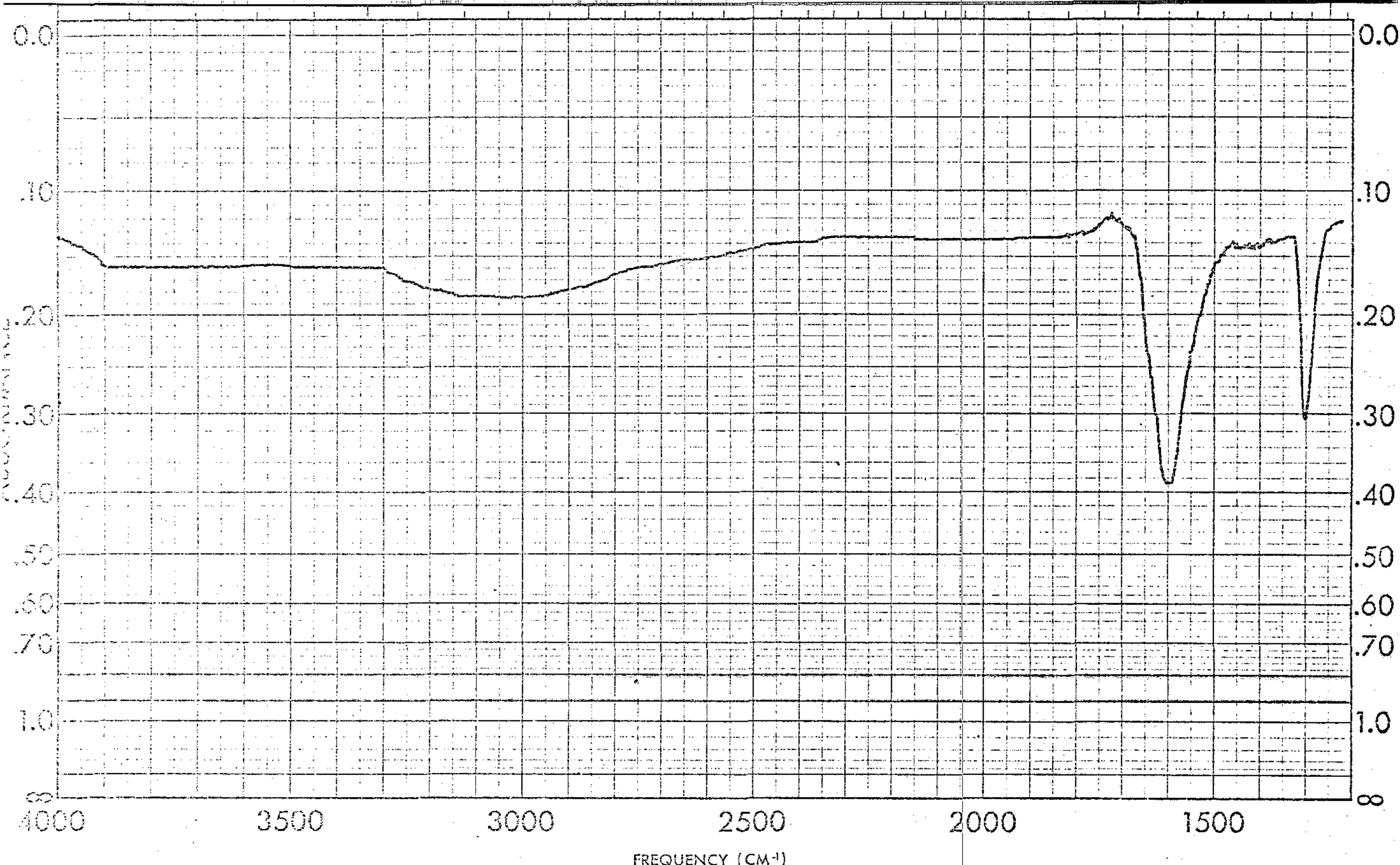
Spectrum No. 110: 50% Magnesium Phosphate, $MgHPO_4$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Calcium Hydrogen Phosphate, $CaHPO_4$ by A.T.R.



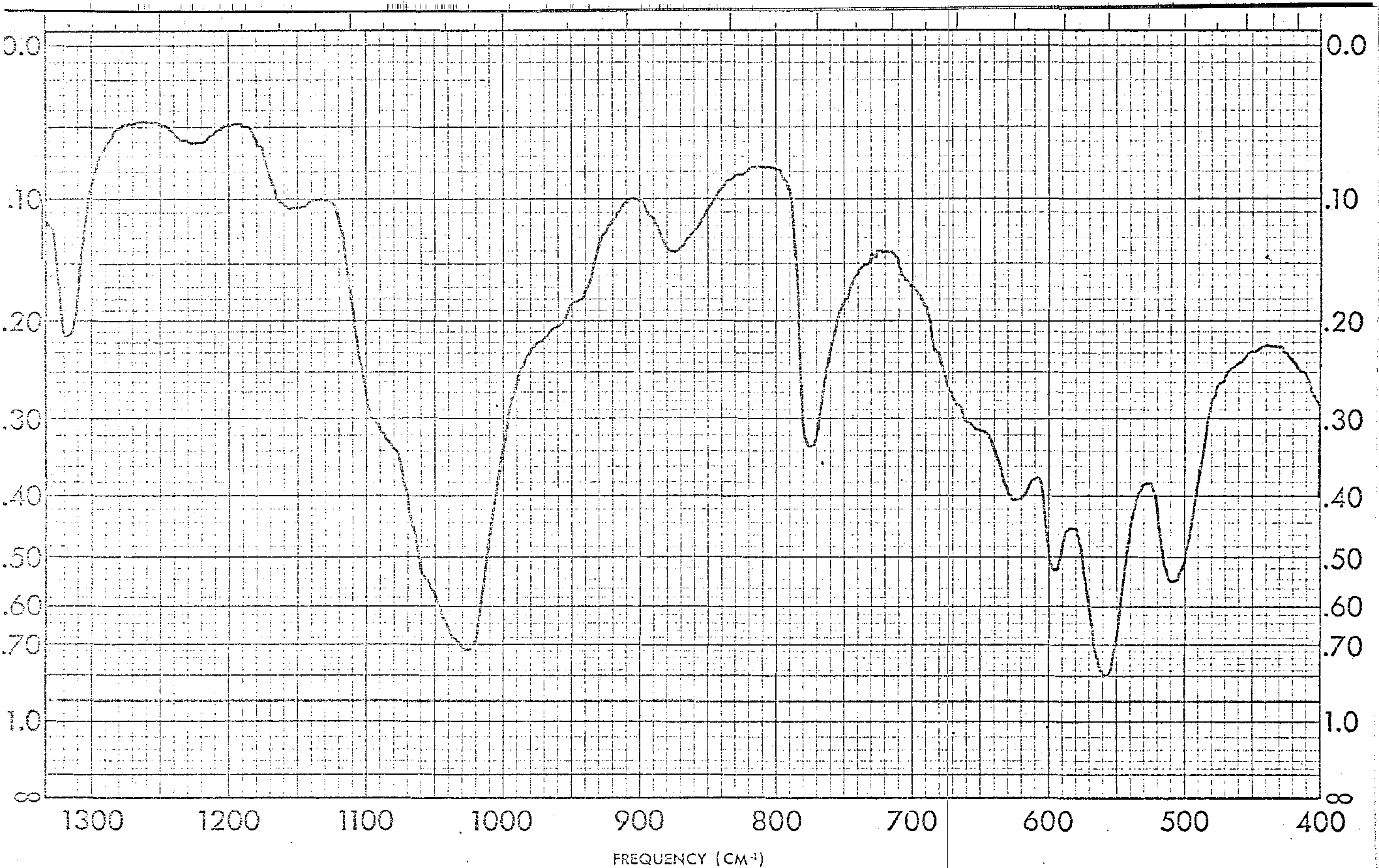
Spectrum No. 111: 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Calcium Oxalate Monohydrate,



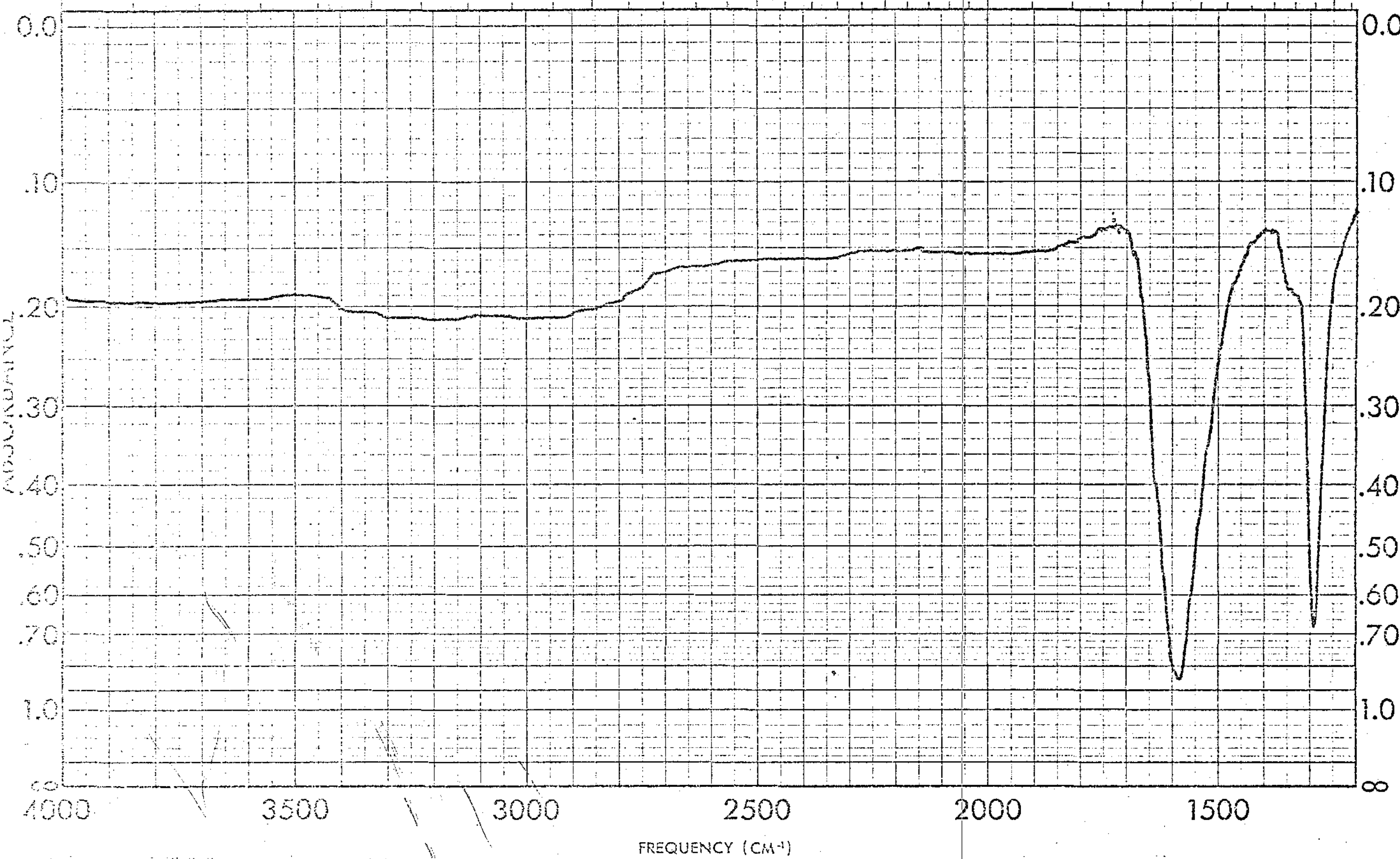
Spectrum No. 111: 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Calcium Oxalate Monohydrate,



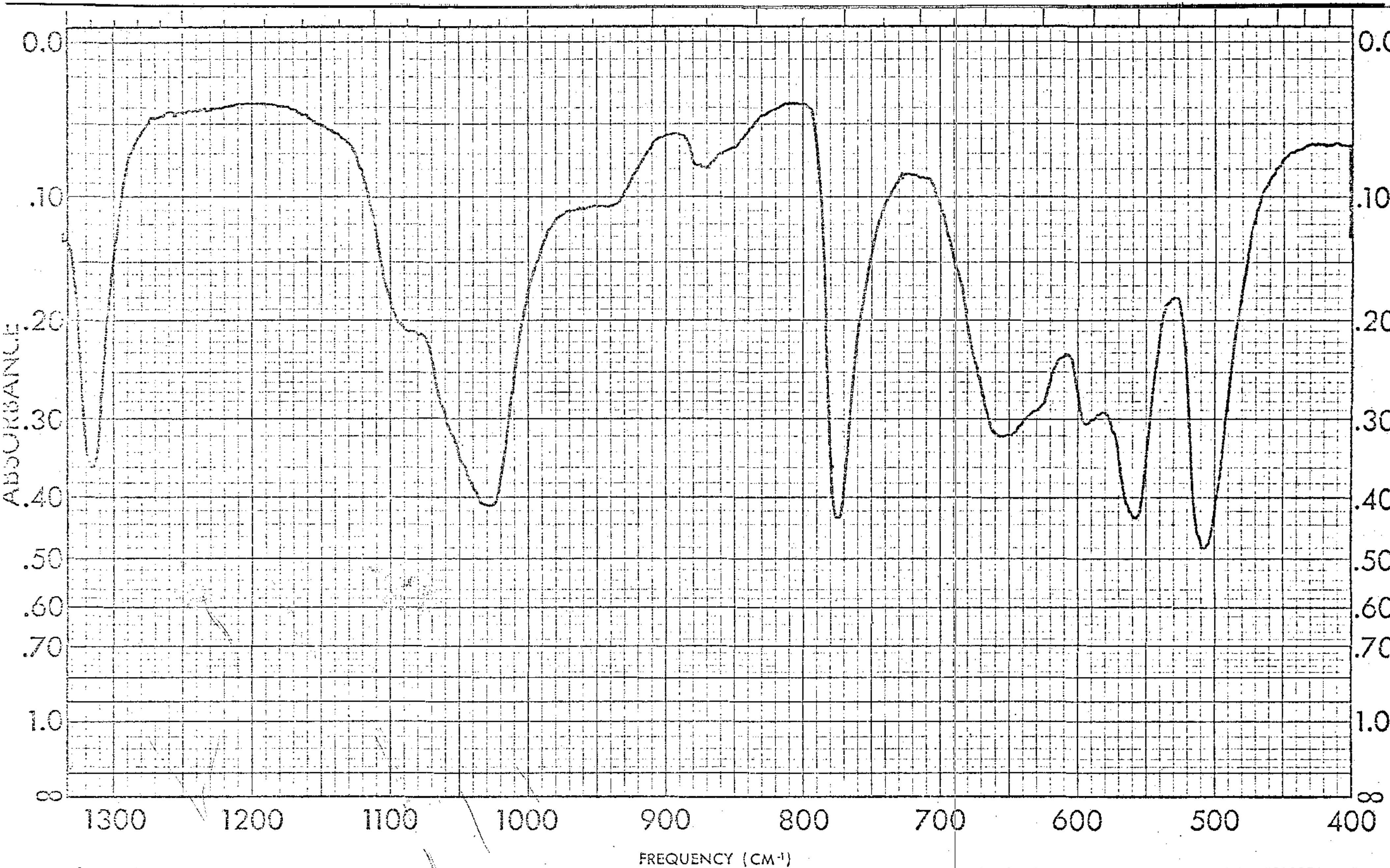
Spectrum No. 112: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



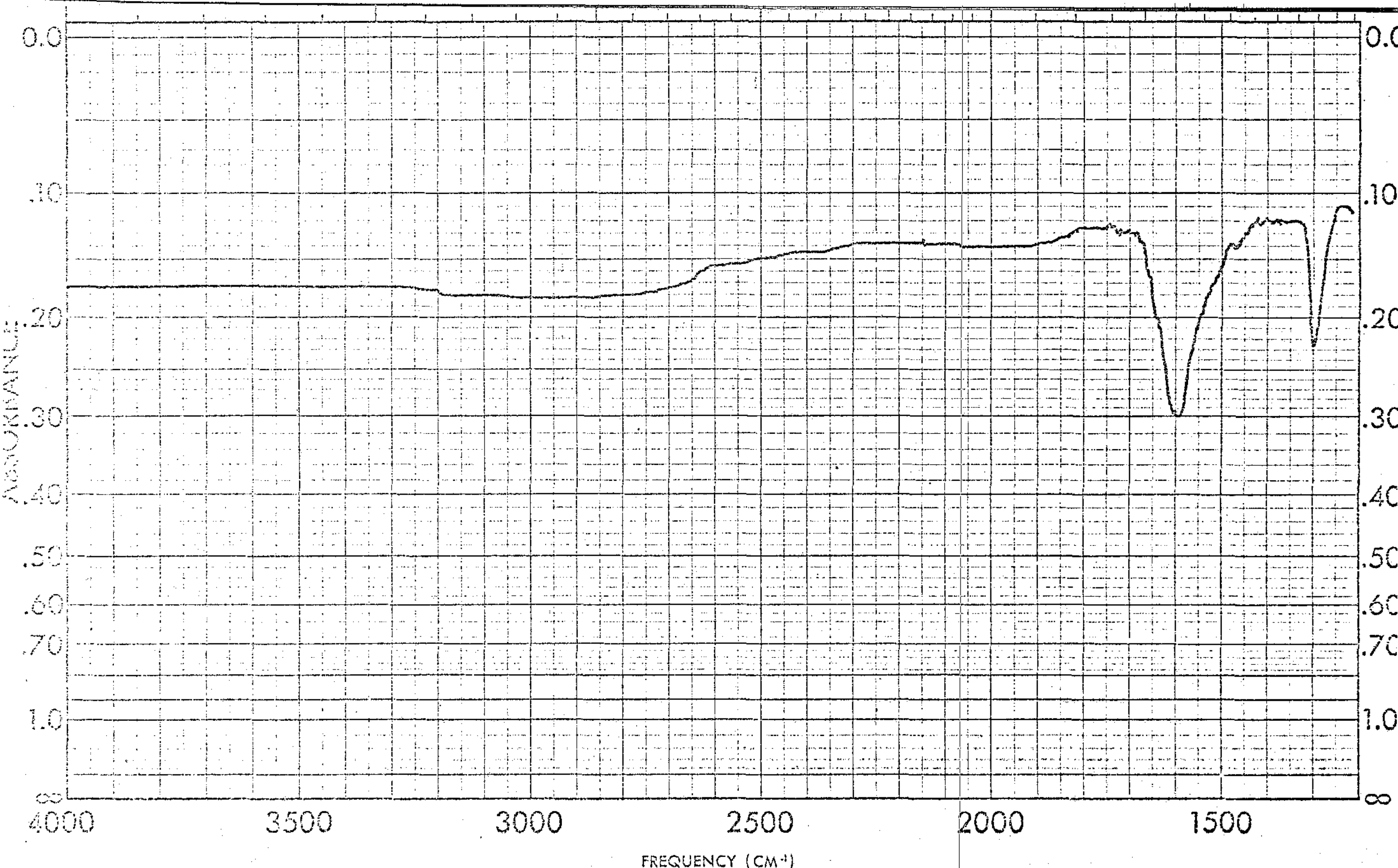
Spectrum No. 112: 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, and 25% Magnesium Phosphate, $MgHPO_4$ by A.T.R.



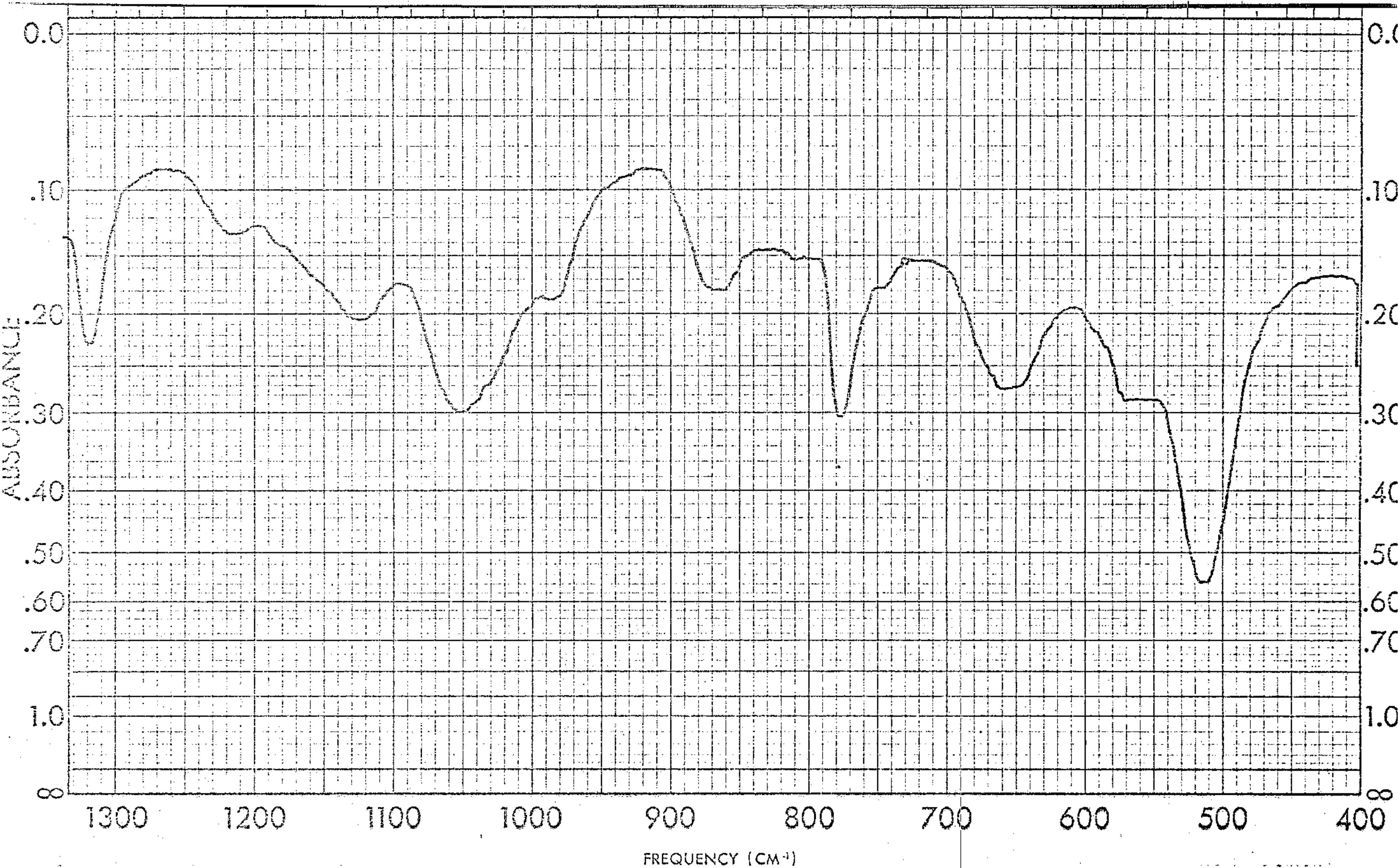
Spectrum No. 113: 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$, by A.T.R.



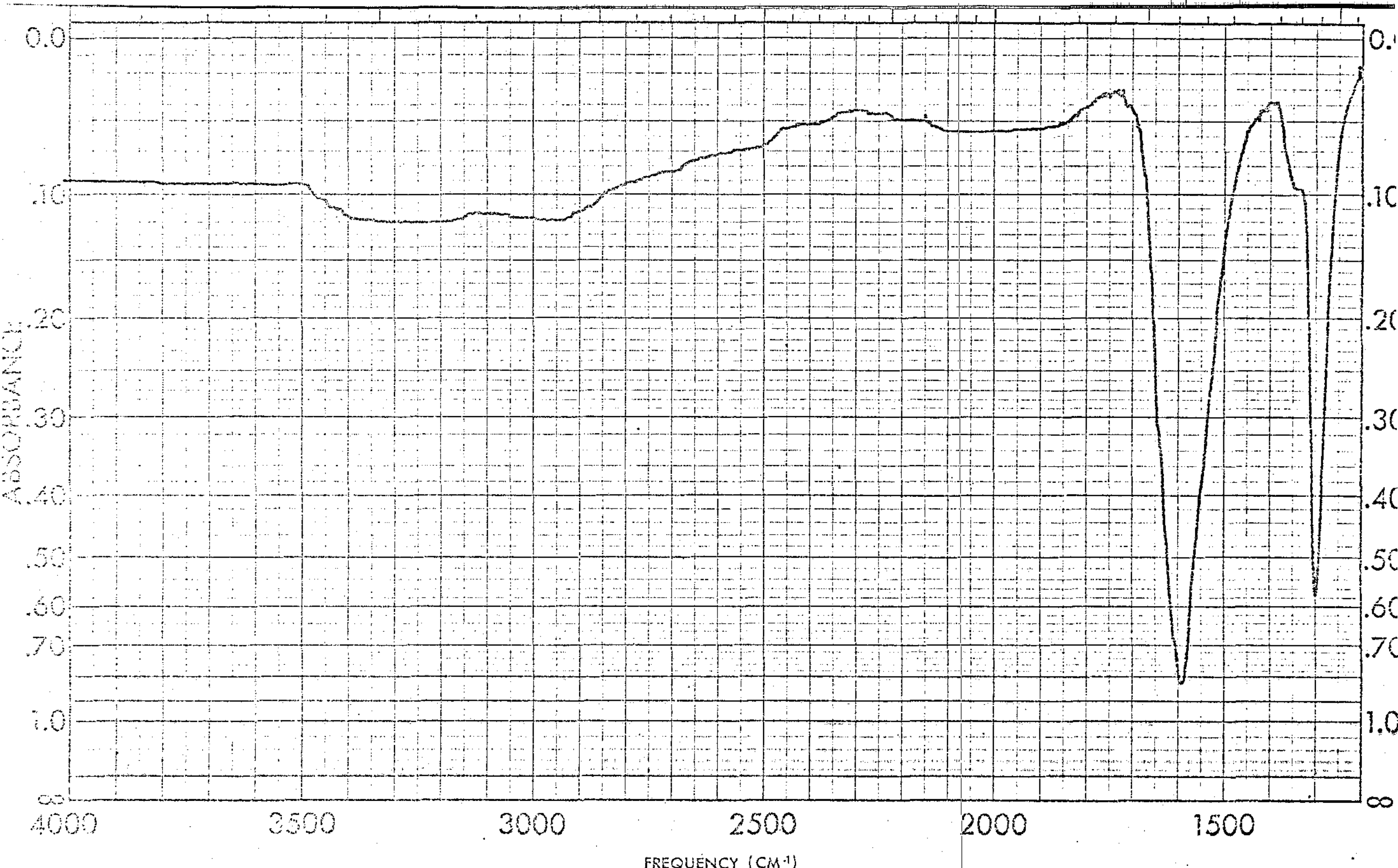
Spectrum No. 113: 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium Ammonium Phosphate, $MgNH_4PO_4$ by A.T.R.



Spectrum No. 114: 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Cystine, $SCH_2CH(NH_2)-COOH$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, and 25% Magnesium Phosphate, $MgHPO_4$

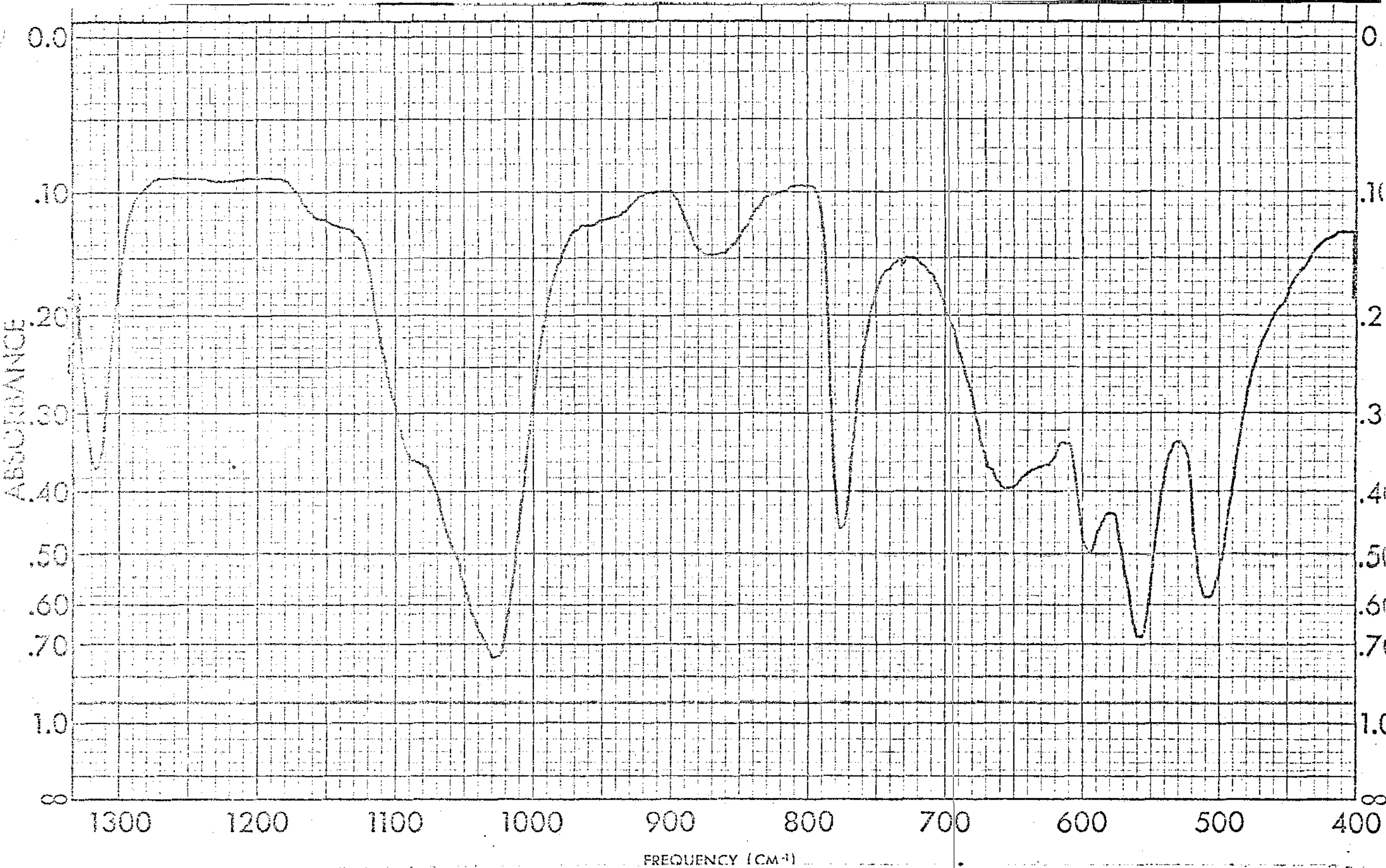


Spectrum No. 114: 25% Calcium Hydrogen Phosphate, $CaHPO_4$, 25% Cystine, $SCH_2CH(NH_2)-COOH$, 25% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$, and 25% Magnesium Phosphate, $MgHPO_4$



Spectrum No. 115: 50% Calcium Oxalate Monohydrate, $CaC_2O_4 \cdot H_2O$, 25%

Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium



Spectrum No. 115: 50% Calcium Oxalate Monohydrate, $CaC_2O_4.H_2O$ 25% Tricalcium Phosphate, $Ca_3(PO_4)_2$, and 25% Magnesium Phosphate, $MgHPO_4$ by A.T.R.